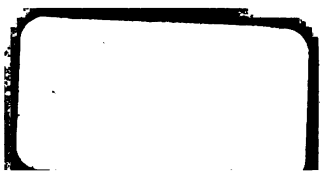

ROLLO'S

PHILOSOPHY.

[SKY.]

THE ROLLO SERIES

IS COMPOSED OF FOURTEEN VOLUMES, VIZ.

Rollo Learning to Talk.	Rollo's Museum.
Rollo Learning to Read.	Rollo's Travels.
Rollo at Work.	Rollo's Correspondence.
Rollo at Play.	Rollo's Philosophy—Water
Rollo at School.	Rollo's Philosophy—Air.
Rollo's Vacation.	Rollo's Philosophy—Fire.
Rollo's Experiments.	Rollo's Philosophy—Sky.

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PREFACE.

The main design in view, in the discussions which are offered to the juvenile world, under the title of The Rollo Philosophy, relates rather to their effect upon the little reader's habits of thinking, reasoning, and observation, than to the additions they may make to his stock of knowledge. The benefit which the author intends that the reader shall derive from them, is an influence on the cast of his intellectual character, which is receiving its permanent form during the years to which these writings are adapted.

The acquisition of knowledge, however, though in this case a secondary, is by no means an unimportant object; and the discussion of the several topics proceeds accordingly, with regularity, upon a certain system of classification. This classification is based upon the more obvious external properties and relations of matter, and less upon those

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which, though they are more extensive and general in their nature, and, therefore, more suitable, in a strictly-scientific point of view, for the foundations of a system, are less apparent, and require higher powers of generalization and abstraction; and are, therefore, less in accordance with the genius and spirit of the *Rollo* philosophy.

As teachers have, in some cases, done the author the honor to introduce some of the preceding works of this class into their schools, as reading books, &c., considerable reference has been had to this, in the form and manner of the discussion, and questions have been added to facilitate the use of the books in cases where parents or teachers may make the reading of them a regular exercise of instruction.

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THE

ROLLO PHILOSOPHY

THE SKY.

CHAPTER I.

OPTICAL ILLUSIONS.

One day Rollo and his father were returning home in a wagon from a ride which they had been taking into the woods. It was quite a large wagon, with two seats. Jonas and little Nathan were upon the front seat, and Rollo and his father sat behind. They had been to get some trees to set out near the house. There was a little spot north of the house, where Mr. Holiday thought that a group of trees would make the landscape more pleasant as seen from the parlor windows. So he had had the ground prepared, and he used to drive out, now and then to

get trees to plant there. The trees which they had got were in the bottom of the wagon, with the tops running out behind. There were a few small evergreens standing up in the bottom of the wagon.

When they had got about half way home, the sky became overcast with heavy, black clouds. They were very black, and Mr. Holiday thought that a shower was coming, and that the whole party would get drenched with rain. But the rain did not come on as they expected, and Rollo leaned back in the wagon, and looked up, in admiration of the vast canopy of clouds which spread over the whole heavens like a dark dome.

"What a great black arch!" said Rollo.

"Yes," replied his father; — "though it is a *dome*, rather than an arch. Do you know what the difference is between a dome and an arch?"

"No, sir," said Rollo, "not exactly."

"An arch," replied his father, "is straight on the two sides, and curves only from one side over to the other; but a dome is round, and curves from every side to a point at the top, like the under side of a bowl."

"Yes, sir," said Rollo, "I understand. So the sky is a dome?"

"Yes," replied his father, "though it is often called an *arch*. But an arch is straight at the two sides, and open at the ends. Do you remember the arches under the chimneys in our cellar?"

"Yes, sir, I remember the arches down cellar; are they under the chimneys?"

"Yes," replied his father. "A chimney is generally supported by an arch below, in the cellar. It wouldn't do to begin to build a chimney on the floor of the house. They must begin on the ground, at the bottom of the cellar."

"Why, sir?" said Rollo.

"Because," replied his father, "a chimney is very heavy — very heavy indeed. Such a column of bricks, extending from the lowest fireplace away up above the roof of the house, would be too great a weight to rest upon the boards and timbers of a floor. So they begin at the bottom.

"But, then," continued his father, "it is not necessary to build it up solid from the bottom. They build two walls, as far apart as the width of the chimney, and then they

arch over from one of these walls to the other, and so found the chimney upon the arch. This saves room in the cellar; for they generally make a little closet in the arch, which is a very convenient place to keep things warm; and, besides, it saves bricks. It would take a great many more bricks to build up a foundation for the chimney solid from the bottom."

"And it saves work too," said Rollo, "I suppose, in laying the bricks."

"Yes," said his father; "so it is better on all accounts. For the arch is very strong — almost as strong as solid work. But you see it is quite different from a dome. The space covered by an arch is square or oblong, while that covered by a dome is round."

"Do they make domes in building houses?" asked Rollo.

"No," replied his father. "I believe not, — unless we consider an oven a dome. An oven is a sort of a dome; that is, it is built on the same principle, only it is oval in its form, instead of round."

During this conversation, Jonas had been driving pretty fast, because he expected that it was going to rain; but now he began to

et the horse slacken his pace a little, as he thought, from the appearance of the clouds, that there would be no rain; and driving very fast seemed to shake the trees and plants so as to threaten to do them some injury.

After a short pause, Mr. Holiday spoke of the subject again. He said, —

"The dome-like appearance of the sky is one of the most remarkable optical illusions in nature."

"What is an optical illusion?" said Rollo.

"An optical illusion?" repeated his father; —"why, it is a kind of a false appearance which any thing makes; such, for instance, as two long rows of trees appearing to come pretty near together at the farther end, while they are really as far apart at that end as they are where we stand. That is an optical illusion.

"So," continued his father, "if you were to put your finger in a tumbler of water, and let Nathan look at it through the side of the tumbler, it would look very large to him; that is, if you were to put your finger down about in the middle of the tumbler. He

would say, perhaps, 'O, what a monstrous great finger!' and you would say, 'No, Nathan, it is only my finger. Its looking large is only an optical illusion.'"

"What would make it look so large, sir?" said Nathan.

"The water, — and the glass side of the tumbler," replied his father.

"But does every thing look large if we see it through water?" asked Rollo.

"No," said his father. "It depends upon how you look at it, and the shape of the glass that the water is in. If you run a stick down a little way into the water in a brook or pond, it makes the stick look bent. That is another optical illusion."

Rollo had often observed this phenomenon when he had been playing in the water, and he told his father so; but he said that he did not know before that it was an optical illusion.

"What makes the stick look so crooked, father?" asked Rollo.

"Why, it does not look *crooked*, exactly," replied his father. "It is only bent in one place, and that is just at the surface of the water. All that part of the stick which is

under the water looks straight, and all that which is above the water looks straight; but the two parts are not in the same straight line with one another. The part which is under water, seems to slope down more than the other."

"Well, sir, and what makes it?" said Nathan.

"You couldn't understand the explanation, if I were to tell you."

"*Perhaps* I could, father," said Nathan. "I wish you would try."

"No," said his father; "you will have to study mathematics, and geometry, and optics, a long time before you can really understand that."

"Couldn't *I* understand it if you should explain it to me?" said Rollo.

"No," said his father, "I think not."

"Well, father," said Nathan, "I wish you would just tell me, and let me see if I can't understand it."

"Well," said his father, "I will. The fact is, that the rays of light from the lower part of the stick, in passing out from the water, come from a denser medium to a rarer, and are refracted, of course, from the

perpendicular. They are consequently depressed, and enter the eye at a smaller angle with the surface of the water than they would have done if their path had been all the way through a uniform medium. This changes the apparent position of every part of the stick which is under water; as objects appear always in the direction of the ray as it enters the eye. That is the explanation; do you understand it, Nathan?"

"Why — no, sir," said Nathan, hesitating, "not exactly."

Rollo laughed.

"I thought you would explain it better than that," said Nathan.

"I was not quite fair," said his father, "I must acknowledge. I could have made it not quite so unintelligible as that, though that is the true explanation, and it would be perfectly intelligible to any one who is prepared to understand such subjects. But it would not be wise for me to attempt to explain the cause of that illusion to you now. All I meant by speaking of it was, to let you know what an optical illusion is. There are a great many kinds of optical illusions."

"What are some of them?" asked Rollo.

"Why, any thing which is off at a distance looks very small. That is an illusion to young children, for they are often deceived by it. Older persons learn to correct the sight, and conceive of a person or a thing which is a great way off as of the true size. Thus, if Nathan were to see a boat coming, with men in it, a great way off upon the water, he would think, perhaps, that the men were boys; but an old sailor, accustomed to see boats upon the water, would look upon them as men. We do not generally call it an illusion, unless it deceives us, or partly deceives us.

"So, when you are sailing down a river, or along the shore of a pond, the trees on the shore seem to move, and young children always think at first that they are moving; in fact, they can hardly believe that they are not moving. It is an optical illusion."

"Well, father, what else?" said Rollo, when his father paused.

"Why, the appearance of the sun, when it first rises in the morning, is an optical illusion. When we see the sun in the morning, and it seems to be just above the horizon, it really *is* just below. Its appear-

ance above the horizon out of its real place is an optical illusion.

"Then the whole apparent motion of the sun," continued Mr. Holiday, "is an optical illusion. The sun does not move at all. The sun does not go round the earth in a day. The earth turns round on its axis before the sun; but the sun appears to move. And this is an illusion which we never learn to correct. We *know* that the sun stands still, it is true; but we cannot make it *seem* to stand still. After sailing up and down a river, or around upon a pond for a long time, we not only know that the banks and the trees do not move, but they cease to *seem* to move. But we never correct our sight in respect to the sun and stars. They continue to seem to us to move, all our lives. We never succeed in making the earth seem to move, and the sun and the stars to be still. So that the apparent motion of the sun and stars is a very obstinate optical illusion."

"Well, father," said Rollo, "tell us some more optical illusions."

"The images in a looking-glass would be considered optical llusions, if we were not

so accustomed to them that they cease to deceive us at all. If a person who had never seen a looking-glass, were to come into a house and see one, he might imagine that there was something behind it, and attempt to take the glass away to look. You might tell him, in such a case, that there was nothing behind the glass; that the image which he saw was an optical illusion."

"Well, father," said Rollo, "what was it that you said, at first, about the sky being an optical illusion?"

"I said that the arched or dome-like appearance of the sky was an illusion."

Here Rollo leaned his head again upon the top of the support which was at the back of the seat that he was sitting upon, and looked up into the sky. The clouds were not so black and threatening as they had been, but they extended, with some broken intervals, all over the sky; and they seemed to form one great swelling dome, as true and beautiful as if it had been mathematically formed.

"Why, father," said he, "the clouds are very high over my head, and all around they come down nearer and nearer to the ground and so they make a real dome."

"No," said his father, "it is all an illusion."

"Why, father!" said Rollo.

"Yes," said he, "that great canopy of clouds is flat."

"Flat? O father!" said Rollo.

"Yes," said his father. "I will explain it to you some day. But now we have got home, and I must attend to setting out my trees. I wish that you would go in and see what time it is."

"No, sir; let me go," said Nathan.

"Why, you can't tell what time it is," said his father.

"Yes, sir, I can," said Nathan; "let me try."

So Nathan clambered down out of the wagon, when Jonas stopped in the yard, and ran in, while Jonas, and his father, and Rollo, began to take out the trees. Presently Nathan came back.

"Well, Nathan," said his father, "what time is it?"

"The long hand, — no, the *short* hand," said Nathan, speaking very deliberately, "is at four ones, and the long hand at a one and an X."

QUESTIONS.

Describe the circumstances in which the conversation recorded in this chapter occurred. What is the difference between a dome and an arch? In what case is an arch commonly built in houses? What example of a dome in common houses? What did Mr. Holiday say of the dome-like appearance of the sky? What is an optical illusion? What optical illusion is observed by children in sailing? What illusions are mentioned in the appearance of the sun? What other optical illusions are mentioned? How did Rollo argue to prove that the dome-like appearance of the sky was not an optical illusion?

CHAPTER II.

THE PROOF.

After tea, on the evening of the day when Rollo and his father had had their ride in the wagon after the trees, little Nathan came into the parlor with a hoop in his hand. His mother was sitting at the window, sewing.

"Look, mother, look," said he, holding up his hoop.

"Ah," said his mother, "a hoop. You've got a hoop."

"Yes, mother," said Nathan; "it is mine — the whole of it. Jonas gave it to me. He got it off a barrel."

"Did he?" said his mother.

"Yes; it is a beautiful hoop. You may drive it, mother, if you want to — some time."

"May I?" said his mother; "well, I am very much obliged to you."

Nathan perceived that his mother did no

take any very great interest in his hoop after all; and so he went out to find Rollo, to show it to him. Rollo and his father were sitting under the piazza, talking about the clouds, and Nathan stopped to listen. The first thing that he heard was Rollo's saying to his father that the clouds were certainly very high up from the ground directly overhead, and that all around at a distance they came down very near to the ground, and so they made a real dome.

"No," replied his father; "they are as far from the ground off at a distance as they are here."

"O father!" said Rollo.

"Why, consider a moment," replied his father. "Do you suppose that, when there is such a canopy of clouds over the sky, if you were to go into the next town, you would find the clouds touch the ground?"

"Why, no, sir," said Rollo.

"Don't you suppose that you would find them as high above the earth there, as they are here?"

"Yes, sir," said Rollo, "I suppose they must be; but they look as if they came down to the ground."

"No doubt," replied his father. "They ook so, I know. It is an optical illusion, as I told you."

"O father," said Nathan, "I wish you would show me the optical illusions in a tumbler."

"Well," said his father, "go and ask Jonas to give you a tumbler nearly full of water, and I will. Can you bring it carefully?"

"Yes, sir," said Nathan. "I won't spill it." And accordingly he went after his tumbler.

While he was gone, his mother, who had heard voices upon the piazza, concluded to come out with her work, and join the party there. So she took a seat by the side of Rollo and his father, and began to listen to the conversation.

When she heard Mr. Holiday say that the arched appearance of the sky was an illusion, she was much surprised.

"You see it must be so," said Mr. Holiday; "for, wherever we go, the clouds appear high directly over our heads, and all around at the sides they come down to the horizon. But, if we were to go off to the next town, —

to the land which is now in our horizon, — no doubt we should find the clouds of the same height there, over our heads, that they are here."

"Yes," said Rollo's mother; "but then the earth is round, and I always supposed that clouds conformed to the shape of the earth; and so their being at an equal distance from the earth every where, instead of making them flat overhead, would make a dome."

"Yes," said Mr. Holiday, "that is true. The earth is round, and the clouds conform to its shape; but, then, for so small a distance as we can see, this roundness is not perceptible. The clouds do make a real dome over our half of the earth; that is, they would if so large a part of the earth was covered with clouds at the same time. But such a dome as that, would be as large as half the earth; that is, it would be eight thousand miles across it. But we do not see any such dome as that when we look up at the clouds now. We could not see such an expanse of clouds as that at all, unless the earth were taken out of the way, and we went and took our places where the centre of the earth now is. If we were to do that, then we should see a real

dome of clouds, no doubt, eight thousand miles across."

"It would be more than eight thousand miles across, father," said Rollo; "for the earth is eight thousand miles across, and the great dome of clouds would be larger, for it would be beyond the earth."

"Yes," said his father, "a very little, — only three or four miles, however; and that would not make any sensible difference in so great a distance as eight thousand. If you were to draw a circle as large as you could draw on a sheet of paper, for the earth, and then attempt to draw another circle outside of it, just as far off as it ought to be to represent the clouds three or four miles from the earth, the outer line would be so near the inner one, that there would hardly be room for a hair to lie between them."

"O father!" said Rollo with surprise.

"Yes," said his father; "the clouds lie very near the earth indeed, compared with the magnitude of the whole globe; so that you see it would be utterly impossible for us to see the real arch or dome of clouds which might be formed around half of the earth from any place on the surface of it. Instead

of being eight thousand miles across, the dome which we see is not often two or three miles across; so that there is no doubt that it is a mere optic illusion."

"Yes," said Rollo's mother, "it must be so, I see; but I never thought of it before."

"Yes," rejoined Mr. Holiday. "If we were in a great building with a flat ceiling over our heads a mile high, and extending several miles every way, there is no doubt that it would look like a dome. And, in fact, we can see the reason why it should."

"What is the reason?" asked Rollo.

"Why, every thing looks smaller to us the farther off it is. And not only objects themselves look smaller, but the distance from one object to another looks smaller. Now, the distance of the ceiling from the ground off half a mile from us, would look smaller than the distance of the ceiling from the ground very near us; and so the ceiling would seem to come nearer and nearer to the ground the farther off we look. And this would give such a ceiling the appearance of a dome."

"Father," said Rollo, "why doesn't Nathan come back with his tumbler?"

"I don't know," said his father. "He

has got engaged in playing somewhere, I presume. But I want you to listen to one more proof that the arched appearance of the sky is an illusion; and that is a proof from the stars. We might suppose the clouds to be spread evenly over our heads, and to be slightly arched, corresponding with the earth. But in regard to the stars, there is nothing of the kind. The sun, moon, and stars, are scattered irregularly in space, some nearer, and others very remote. There is nothing like an arch or curve of any kind about them. And yet, when we look up in the evening, they are all brought into the same surface, and that surface takes the form of a beautiful dome. It must of course be *entirely* an illusion in that case."

"Father," said Rollo, "how high are the stars?"

"O, they are too far off," said his father, "for you to have any conception of the distance, if I were to tell you."

"Well, how high are the clouds, then?" asked Rollo. "You can tell me that."

"They are of very different heights," said his father. "Some clouds touch the earth and some are several miles high."

"Do some clouds touch the earth? I never saw one."

"Yes," said his father. "You have seen mists and fogs, and they seem to be only clouds lying upon the earth."

"I did not know that," said Rollo. "I thought fogs and mists were very different from clouds."

"No," said his father; "they are the same."

"How do you know, father?" said Rollo.

"The philosophers have ascertained in various ways," replied his father. "Clouds sometimes lie against the sides of the mountains, and, as we know how high the mountains are, we know how high the clouds are. I believe they have a way, too, of finding out how high a cloud is by the shadow it casts."

"How do they do it?" asked Rollo.

"I don't know," replied his father, "how it is done; but I believe they have a way."

"I shouldn't think they could find out any thing by the shadow."

"Yes," said his father; "you know you can measure how high the steeple of a church is by its shadow, — or a house, or a tree."

"No, father," replied Rollo; "because sometimes the shadows are very long, and

sometimes they are very short; and so we can't tell any thing by the shadow."

"Yes," rejoined his father. "Suppose you put a stake into the ground so long that it is just one foot above the ground. Then in the morning you look at the shadow. You know it will be very long."

"Yes, sir," said Rollo.

"Because," continued his father, "the sun has not risen very high, and so the rays shoot away beyond the stick, and make the shadow extend a long way on the ground."

"Yes, sir," said Rollo.

"Now, if you wait a little while, till the sun rises higher, and then look at the shadow again, will it be longer or shorter?"

"Shorter, sir," replied Rollo.

"Right," replied his father. "Now, you can watch it until you find that the shadow is just as long as the stick itself. And then, when the shadow of a stick one foot high is just as long as the stick, the shadows of every thing will be just as long as the objects that make them. Then you have only to go and measure the shadow of a tree, and that will tell you how high the tree itself is And so with a house, or a steeple, or any

other thing so tall that you cannot get at the top of it to measure it."

"Yes, father, I understand; and I think it is an excellent way."

"I think it is a very good way indeed," said Rollo's mother.

"I mean to measure how high our house is, to-morrow," said Rollo. "I'll get Jonas to help me."

"It is not necessary," continued his father, "to wait until the shadow is as long as the stake. If it is twice as long, it will do just as well, because then you would only have to measure the shadow of the house, if it was a house that you were going to measure, and then take half the length of the shadow, and that would be the height of the house. For if half the shadow of the stake was as long as the stake itself, half the shadow of the house would be the height of the house itself; for all shadows made by the sun at the same time, are in the same proportion."

"Yes, sir," said Rollo; "though that would not be quite so easy."

"No," replied his father, "it would not be quite so easy; but it might save you some time, in waiting for the shadow to get just

equal. And so, if the shadow was too short, — for instance, if it was only half as long as the stake, — then the shadow of the house would be half the height of the house. In that case, you would have to measure the shadow of the house, and then double it."

"Yes, sir," said Rollo.

"And if you were a mathematician," continued his father, "it would be of no consequence how long the shadow was in reference to the stake, because you could calculate. You could write down the length of the shadow of the stake, and the length of the stake itself, and also the length of the shadow of the house, and so make a calculation. But as you are not a mathematician, it would be better, if you undertake to measure in this way, for you to wait until the shadow is just equal to the height of the object, or half as long, or twice as long; for then you could calculate easily."

"Well, sir," said Rollo, "I'll wait till it's just equal, and then I shall be sure.

"And now I wish Nathan would come back. I don't see what has become of him. I mean to go and find him."

Rollo accordingly left his father and moth-

ei and went in pursuit of Nathan. He found hi in the kitchen, standing at a table with a tumbler of water before him, which he seemed just ready to take up and bring along, only he was talking to Dorothy.

"There isn't, Dorothy," said Nathan, in a very positive tone.

"There isn't what?" said Dorothy, who was busy with her work, and was not paying any particular attention to what Nathan was saying.

"There isn't any sky.'

"Isn't there?" said Dorothy.

"No," replied Nathan. "There isn't any sky at all. There are some clouds, and some stars; but," continued he, shaking his head very seriously, "there isn't any sky."

"Ah," said Dorothy.

"No," said Nathan, "nor any dome. It's all a ——" Here Nathan hesitated, not being able to recollect the word.

"All a what?" asked Dorothy.

"I don't remember what the word is," said Nathan. "It is something which father is going to show me in this tumbler. I don't remember what the word is, but I know what it means."

"What does it mean?" asked Dorothy

"It is something that means mistake."

"Come, Nathan," said Rollo; "we are all waiting for you."

"Yes," said Nathan, "I'm coming."

QUESTIONS.

What illusion was it that Mr. Holiday was going to show the children by means of the tumbler of water? How did he show that the dome-like appearance of the sky was an illusion? Did he maintain that the canopy of clouds was perfectly flat? What did he say about the height of the stars? What about the height of the clouds? How did he say that the height of the clouds had been ascertained? Explain the process by which he first proposed to Nathan to measure the height of a steeple by its shadow. Was it absolutely necessary to wait until the shadows were equal to the objects which cast them? Did Rollo conclude to try the experiment? What did he say that he intended to attempt to measure?

CHAPTER III.

APPARENT MAGNITUDE.

One summer afternoon, Miss Mary, who for a time taught a school where Rollo used to go, as is described particularly in the book entitled "Rollo at School," invited Rollo and his cousins Lucy and James to come and take tea with her. They all went. In the evening, after tea, they were going out to take a walk. Miss Mary was not quite ready. Lucy and James were sitting at the table, looking at some picture-books which Miss Mary had given them to amuse themselves with while they were waiting for her. Rollo was looking out at the window, and all at once the attention of Lucy and James was taken off from their books by hearing Rollo call out, —

"O, come and see this great fire!"

They all went to the window. There was, indeed, what appeared to be a great blazing fire, away across a valley which they

looked upon from the windows of the house There were two large trees, and the fire appeared to be between the trees. Rollo thought that it was a house on fire, and that the two trees were before the house. The fire filled up the whole space between the trees.

"It must be a house," said Rollo, "and a very large house too."

"I guess it is a meeting-house," said James.

"I guess it is the moon," said Miss Mary.

"The moon!" repeated Rollo. "It is a great deal too large for the moon. The moon is not as big as that."

"How big is the moon?" said Miss Mary.

"Why — yes," — said Rollo, "I know the moon is actually as big as a house; but I mean it does not look as big as that."

"How big does the moon look?" said Miss Mary.

"Why, about as big as a large plate," said Rollo.

"O Rollo," said James, "it looks bigger than a plate. It looks as big as a cart wheel."

"It looks about as big as the top of a hat

to me," said Lucy. "It looks different to different persons, I've heard people say."

"That is a mistake," said Miss Mary "It looks about the same to all people."

"But, Miss Mary," said Lucy, "Rollo says it looks as big as a plate to him, and James says it looks as big as a cart wheel to him. I should think they would know."

"They do know," said Miss Mary.

"Why, one or the other of them must be mistaken," said Lucy, "if it really looks the same to them both."

"No," said Miss Mary, "I don't think that either of them is mistaken."

"Why, Miss Mary," said Lucy, "how can that be?"

"It seems strange," replied Miss Mary, "I know; but so it is. I have no doubt that the moon looks as big as a cart wheel to James, and as big as a plate to Rollo, and yet it looks just as big to one as it does to the other."

"O Miss Mary," said James, "a cart wheel is a great deal bigger than a plate."

"Yes," said Miss Mary, "and yet what I say is true, and I presume I can prove it to your satisfaction."

"You've got a pretty hard thing to prove Miss Mary," said Rollo, "*I* think."

"I am not certain that I can prove it to your satisfaction; but I am certain that it is true, at any rate."

By the time that this conversation was concluded, there was no longer any doubt that the great light which the children had seen was really the moon; for it had risen a little, and its round form could be seen, large and full.

"What a large moon!" said Rollo.

"How large does it appear to you to be now?" said Miss Mary; "as large as a cart wheel?"

"No," said Rollo; "but it looks larger than usual. It looks as large as a very large plate indeed."

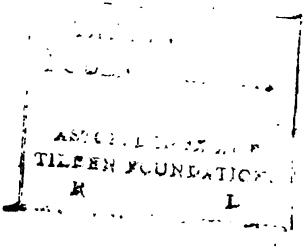
"But you said, a few minutes ago, that it looked as large as a house."

"Well, it did then," replied Rollo; "but it has got up higher now, and I can see it better."

"Don't you see that it just fills the space between two trees?" said Miss Mary.

The moon had in fact risen a little, but it was still between the two trees, and it was just large enough to occupy the space be

"WHAT A LARGE MOON," SAID ROLLO.—Page 40.



tween them, just as it had done when it began first to peep up above the horizon.

"Yes," said Rollo, "it does."

"And did it more than fill the space between the trees when it was lower down and you thought it was a house on fire?" asked Miss Mary.

"No," said Rollo.

"Then doesn't it look just as big now as it did then?"

"No," said Rollo; "it looked as big as a house then, and it does not now. It does not, — *certainly*, Miss Mary."

"But consider a moment, Rollo. Suppose you could reach your hand out, and move the moon back down to the horizon again, and keep it between the two trees; don't you see that you wouldn't change the size of it. The trees are just as far apart at the bottom as they are higher up."

"Yes," said Rollo; "I didn't think of that."

"So that, although it looked as big as a house before, and only as big as a plate now, yet, after all, it looks just as big now as it did then."

"I don't see how that can be," said Rollo

"But yet you see that it *must* be," said Miss Mary. "For the measure of the breadth of the moon now, is the distance between the two trees; and the measure when it was first rising was the same; and of course its apparent size cannot have altered."

Rollo was puzzled. In fact, all the children were puzzled too. They saw that Miss Mary's arguments were entirely unanswerable; but yet they could not understand how a thing could look as big as a house, and then afterwards only look as big as a plate, without appearing to grow smaller.

"Now, children," said Miss Mary, "I will try to prove to you that the moon does not look bigger than a wafer."

"O Miss Mary!" exclaimed the children.

Miss Mary said nothing to their exclamations, but she opened a little drawer in a table which stood in a corner of the room, and took out a pencil and a paper. She gave them to Lucy, and asked her to put the paper up to the window in such a place that she should see the moon by the side of the edge of the paper.

"There," said she, "I want you to draw a little circle on the paper, just as large as the moon. By having the moon right by the side of the paper, so that you can compare your drawing with it, you can see. And you, James and Rollo, must not see her do it. You must go to another part of the room, and, when Lucy has finished her drawing, you shall try too."

So Rollo and James went to the table, and began to look at the picture-books, standing with their backs to Lucy, in order that they might not see how big she made her moon. Presently Lucy told Miss Mary that she had made it.

"Very well," said Miss Mary. "Now, hold up your paper upon the glass again, and bring your drawing and the moon as close together as you can, and compare one with the other, and see which looks the biggest. Perhaps you can slip your drawing directly over the moon, and see whether it is big enough to cover it exactly or not."

Lucy was very busy for a moment or two comparing her circle with the circumference of the moon, and then she said that hers was a little too big.

"Then make another, a little smaller," said Miss Mary.

Lucy made another, and brought it to Miss Mary. She put it in the drawer without letting the other children see it. Then she gave Rollo a piece of paper, and let him make a drawing of the size of the moon, as it appeared to him; and lastly James tried. When the drawings were all ready, she placed them upon the table side by side, and let the children look at them all together.

"There," said Miss Mary, "there are your representations of the apparent size of the moon, and there is not one of them that is as big as a wafer!"

The children did not know what to say in reply to this reasoning.

"The explanation of the mystery is this," said Miss Mary. "Things appear of very different size, according to the distance they are from us. A ship, for instance, when it is near, appears very large; but, when it is away off in the horizon, it looks like a mere speck. So a cart wheel looks large near us, but at a distance, it looks very small."

"Why, now, Miss Mary," said Lucy, "I think a cart wheel always looks of the same size."

"No," said Miss Mary, "you are deceived in that. It is true that, when you see a cart wheel at a distance, you know what it is, and so you know about how big it must be; but in its mere appearance it is small. When we look out of the window, a wafer on the glass would fill the eye as much as a large house away off on the hills.

"So when James," continued Miss Mary, "says that the moon looks to him as big as a cart wheel, he does not mean a cart wheel close to his eye. If we were to put a cart wheel up to the window where you put the papers to make your drawings, it would be big enough to cover twenty moons. And then, again, if the cart wheel was a mile off, hoisted up into a tree where we could see it, and the moon were to rise near it, we should see that the moon would then appear much larger than the wheel.

"Thus," continued Miss Mary, "you see that, when any body says how large the moon appears to be to him, it all depends upon how far off he imagines the thing to be that he compares with the moon. And the way that I took to make the moon appear smaller than a wafer to you was, to make you draw

a representation of it on paper which you had to hold pretty near your eye. If I could have hung up a monstrous great sheet of paper, away off by those two trees, and you had arms long enough to reach there, you would have had to make your drawing of the moon as large as the whole space between the trees."

"O Miss Mary!" said Rollo.

"Certainly," replied Miss Mary; "for you remember that the moon itself filled up that whole space, and of course, if the drawing was made to look as large, that would have to fill it up too.

"And now," continued Miss Mary, "I want you to remember this general principle, which we learn from all these things, — namely, that apparent distances, and the apparent magnitude of objects in the sky, cannot be measured by comparing them with distances and objects about us on the earth. If any body were to say that the moon appeared to be a foot across, or a yard, or a mile across, he would not give any definite information at all. And it would be the same if he should say that the distance from one star to another, as it appears in the sky, is a mile,

or a rod, or four yards. They have a very different way of measuring distances and dimensions in the sky."

"How do they do it?" asked Lucy.

"I will tell you presently, when we go out to take our walk. I am almost ready."

Miss Mary then took up the books which the children had been looking at upon the table, and put them away. She also was going to put away the drawings which the children had made of the size of the moon; but Lucy wanted hers, she said, to carry home and show to her mother. James and Rollo then wanted to take theirs too. In a few minutes after this, the room was all arranged, and the children went out with Miss Mary to take a walk.

QUESTIONS.

Where were the children when the conversation took place, which is described in this chapter? Who were the persons engaged in it? What incident introduced the conversation on the apparent size of the moon? How large did Lucy say that the moon appeared to her? What did Rollo say? James? What was it that Miss Mary

said on the subject, which perplexed the children very much? How did she prove that the moon did not appear bigger than a wafer to them? What circumstance does the apparent magnitude of any object depend chiefly upon? Can we, then, estimate magnitudes and distances in the skies by comparing them with objects on the earth?

CHAPTER IV

DEGREES.

NEAR the house where Miss Mary lived was a little hill with a path through the trees leading to the summit. Miss Mary said that they would go up to the top of that hill, for there they could see the stars and the sky better; and she said that she was going to tell them something about the stars and the sky.

The view by the moonlight from the top of this hill was very beautiful. One side of the landscape at a distance was pretty level, and the sky came down and met the ground in a smooth line. On the other side there were some mountains, and the moon tipped their summits with a silvery light. There were a number of floating clouds in the sky; and the moon was sometimes wading through them, and sometimes it shone out clear. There were not a great many stars.

"Now," said Miss Mary, "I am going to

explain to you how they measure and denote distances in the sky; and you must attend as carefully as if you were listening to a lecture.

"The first thing to explain to you," said Miss Mary, "is the horizon. Do you know what the horizon is?"

"Yes," said Lucy; "the line where the sky and the land meet."

"That is commonly called the horizon,' said Miss Mary, "but that is not it exactly. For instance, look out that way where the mountains are. Does the horizon run along on the tops of the mountains?"

"No," said Lucy, "I suppose not. I suppose the horizon is where the land would meet the sky if the mountains were taken away."

"That is right,' said Miss Mary. "The horizon is the line where the land would meet the sky if the land was perfectly level. We can see the exact horizon when we look off upon the sea; but we never can see it upon the land, because the land is never precisely level.

"However," continued Miss Mary, "the line where the sky and land meet is pretty

near the horizon, and it will answer to represent the horizon. Look at the horizon all around; it is a great circle. If we begin here," said Miss Mary, pointing out to the horizon before her, "and then move round and follow it," — and so saying, Miss Mary turned slowly, keeping her hand extended towards the horizon, — "we shall come round through the whole circle, and back to the place where we began. So the horizon is a circle.

"Now, let me ask you one question," continued Miss Mary, "to see whether you understand what I have been saying. Suppose we could see a star just peeping over the tops of the mountains, out that way, would it be *above* the horizon, or *below* the horizon, or *in* the horizon?"

"Above the horizon," said all the children

"That is right," said Miss Mary.

"Now, look up in the sky, and find the point that is exactly over your head."

The children all immediately began to look up.

"It's right there," said James, pointing up, — "there, by that bright star."

"Is that *exactly* in the centre?" asked Miss Mary.

"No, not exactly," said Lucy. "The centre is a little farther *that* way." So saying, Lucy gestured with her hand to show which way she meant.

"That is the *zenith*," said Miss Mary. "The point in the sky that is exactly over our heads in the centre, is called the *zenith*."

"I can't see the zenith," said James.

"O dear me!" said Rollo, "how it makes my neck ache to look at the zenith!"

The children all found that holding their heads back in such a position was painful, and so they desisted.

"I know you cannot see it," said Miss Mary, in answer to James; "there is nothing there that you can see."

"Then how do you know that there is any zenith?" said he.

"Why, suppose we were in the house, and I were to ask you to take a pin and stick it down through the carpet into the floor exactly in the middle of the room, and you were to go and try to find where the middle of the room was; should you expect

to see any mark or sign by which you would know the middle of the room?"

"No," said James.

"And suppose Rollo should say there was not any middle to the room, because you could not see it, what should you tell him?"

"Why, there must be a middle somewhere," replied James, "even if I could not find it exactly."

"What is the middle?" asked Miss Mary.

"Why, it is — it is just half way from one side to the other."

"Yes," said Miss Mary; "it is nothing that you can see. It is only an imaginary point, which you have to find by instruments."

"Yes," said James.

"It is just so with the zenith. There is no mark in the sky at the place; but there must be a point there, somewhere, which is exactly over our heads, though we cannot see it. By looking up, we can see pretty nearly where it is; but we cannot find it precisely without instruments."

"What kind of instruments?" asked Lucy.

"I do not know," said Miss Mary; "but I

know that the astronomers have some kind of instruments by which they find the zenith when they wish.

"We cannot see precisely where either the horizon or the zenith is," she continued, "though we may know what they are; and we can see pretty nearly where they are.

"The whole horizon," continued Miss Mary, "is a circle; and half of the horizon is half a circle. That is, if we begin at any place in the horizon, and go round till we come to the point exactly opposite to it, we go over half a circle. Do you see that little light out that way?" said Miss Mary, pointing.

"Yes," said Lucy; "it is a star just coming up."

"Perhaps so," replied Miss Mary, "or perhaps it is a light burning in a house; never mind which; for it will do, in either case, to mark a place in the horizon. Now, let us look opposite to it on the other side of the horizon, and see if we can find any thing for a mark there."

The children all turned and looked. The mountains were on the side of the horizon opposite to the light. They selected one

which was higher than the rest, and which seemed more exactly opposite to the light than the rest.

"Now," continued Miss Mary, "if we begin at the star, and pass round in the horizon,"—and so saying, Miss Mary pointed to the star, and then moved slowly around, carrying her finger along the line of the horizon, —"until we come to the mountain, we shall have gone over just half of a circle. Do you understand that?"

The children said that they did. In fact, they thought that it was very easy to understand.

"Now," continued Miss Mary, "if we begin at the star, and, instead of going round in the horizon, go over through the zenith, and so down on the other side to the mountain, that will be just half a circle too; because the dome of the sky is shaped like just half of a ball, and so it will be half of a circle from any place in one side, over through the top, down to the other side.

"Now answer me some questions," said Miss Mary. "How large a part of a circle will it be, from the light up through the

zenith, and down on the other side to the mountain?"

"Half a circle," said all the children.

"And how large a part of a circle will it be from the light up to the zenith?"

"Quarter of a circle," replied Lucy.

"Yes," said Miss Mary; "and how much from the zenith down to the mountain?"

"Quarter of a circle," said all the children.

"And so from the zenith down to the horizon, at any place, will be a quarter of a circle," said Miss Mary. "Now, they divide such a quarter of a circle into ninety parts, which they call *degrees;* and they measure objects and distances in the heavens by the degrees."

"How much is one degree?" asked Lucy

"About twice as much as the breadth of the sun," replied Miss Mary. "For the disk of the sun is about half a degree in diameter. If the sun were to come so much nearer to the earth as to look twice as large every way, then the breadth of the sun would be a degree."

"And the moon," said Lucy, looking out at the same time towards the moon, "how broad is the moon?"

"It is just about as big as the sun," said James.

"Yes," said Miss Mary; "so that the diameter of the moon is about half a degree. In reality, the moon is a great deal smaller than the sun; but then it is so much nearer, that it occupies just about the same place in the heavens. If there was a great balloon, as big as a house, rising up before us, and very near, it would perhaps be eight or ten degrees in apparent magnitude. But as it went off to a greater distance, it would grow smaller, until it filled only a space of half a degree in the sky, when it would look about as large as the sun. If it went off farther still, it would look smaller and smaller, until it was only a quarter of a degree in diameter. At last, it would be just ready to vanish, and then its diameter might perhaps be only a minute."

"A minute?" said Lucy.

"Yes; a minute is only a very small part of the circle of the sky."

"How small?" asked Lucy.

"O, very small indeed," said Miss Mary. "It takes sixty minutes to make a degree.

How many minutes would there be in the diameter of the sun?"

The children did not answer.

"Why, you remember that I told you that the diameter of the sun is about half a degree, and, as a degree is sixty minutes, the diameter of the sun would be thirty."

"And the moon too," said Rollo.

"Yes," replied Miss Mary, "the moon is the same. So that if you can imagine how much one thirtieth part of the diameter of the moon is, you will know how much a minute is."

"I should think a bright star was about a minute," said Lucy.

"Yes," said Miss Mary; "perhaps the appearance of a large bright star comes nearer to it than any thing else we can compare it to; or one of the horns of the moon, near the tip, when the moon is new. Though a minute is too small to be seen very distinctly by the eye. They measure it with very nice instruments. Can you remember how many degrees it is from the zenith down to the horizon?"

"Ninety," said Lucy.

"Yes," said Miss Mary. "Now, Lucy point up to the zenith."

Lucy did so.

"And, Rollo, you may point to the light in the horizon."

So Rollo pointed to the light. Thus they stood, James with his arm extended upward, and his finger directed towards the point in the sky which was directly over his head, and Rollo with his arm extended horizontally, and his finger towards the light.

"Now, Lucy," said Miss Mary, "I want you to point to the place in the sky which is exactly half way between the light in the horizon and the zenith."

Lucy did so. She looked first at the light, and then at the horizon, and, measuring the distance with her eye, she divided it as nearly as possible, and then pointed to the middle.

"Now, from the light to the zenith is ninety degrees," said Miss Mary; "and of course from the light to the place where Lucy is pointing is half of ninety degrees. Half of ninety is forty-five; and, of course, Lucy is pointing to the place in the sky which is forty-five degrees above the horizon.

It is also forty-five degrees below the zenith. Now, I want you to notice how great the space is, so that you will know how much forty-five degrees is."

The children looked at the place where Lucy was pointing, and then from that place down to the horizon, so as to see how much forty-five degrees was. Then Miss Mary told them that they might all put down their hands.

"Now," said Miss Mary, "look all over the sky, and see if you can find a cloud which extends over as much as forty-five degrees of the sky."

The children all looked, but they said that there was no cloud large enough. There were a few small white clouds floating near the moon, but they were all much less than forty-five degrees in extent.

"There is a cloud which the moon is just going into," said Miss Mary. "How large is that cloud?"

The children hesitated. They did not know exactly how to go to work to estimate it.

"You can tell by comparing it with the moon."

It is about twice as wide as the moon," said Lucy.

"Then how wide is it in degrees?" asked Miss Mary.

"Why, one degree," said Lucy, "if the moon is half a degree."

"Yes," said Miss Mary; "so that that cloud shows you very nearly how much one degree is. Now, how many degrees long is it?"

Lucy thought it was three degrees long, and James and Rollo, two degrees. Miss Mary said that perhaps it was between two and three. "And now, children," she continued, "you have studied enough for one lesson, only there is one thing that you must understand and remember; and that is, that a degree is not any particular length in feet or yards; it is only the apparent space in the heavens which the object occupies. The number of feet or yards included in a degree depends altogether upon how far off the thing is. A balloon a mile from us might be half a degree in diameter, and so be as large in degrees as the sun, which is a million of times as big as the balloon; so that half a degree on a balloon a mile from

us, would not be more than forty or fifty feet; but at the distance of the sun, it would include many thousand miles."

Miss Mary and the children then went down the hill, and returned to the house. On their way, Rollo told Miss Mary what his father had told him about the dome-like appearance of the sky being an optical illusion.

"Yes," said Miss Mary, "it is, I have no doubt."

"And he told us about several other optical illusions," said Rollo.

Lucy asked what they were, and so Rollo told her. Miss Mary said that they were very remarkable, but that she knew one optical illusion which was a little more remarkable. she thought, than all those.

"What is it?" said Lucy.

"The rainbow," said Miss Mary.

"The rainbow!" exclaimed the children "Is the rainbow an optical illusion?"

"Yes," replied Miss Mary, "I believe it is. I believe there is no rainbow except in people's eyes."

"O Miss Mary!" exclaimed the children

"And no two persons see a rainbow in the same place," said Miss Mary.

The children were very much surprised at these statements, and thought that Miss Mary must be mistaken. She said, however, that she could not explain it to them then, but that, if they would come and see her some other day, she would tell them about the rainbow. "And, in the mean time," said she, "whenever you see any thing in the sky, try to estimate its magnitude in degrees, and that will fix in your minds what I have told you."

QUESTIONS.

Where did the children go, when they went out to their walk? What is the horizon? Could the children actually see the horizon? What is the name of the point exactly overhead? Could the children find the zenith exactly? How large a part of a circle is it from the zenith down to the horizon? How many degrees are there in a quarter of a circle? Is the apparent breadth of the sun more or less than a degree? What did Miss Mary say about a balloon? What did Miss Mary mention, at last, as a most remarkable optical illusion?

CHAPTER V

CLOUDS.

The children thought no more of Miss Mary's promise to explain what she had said about the rainbow, for some weeks after this. Perhaps they never would have thought of it again, if it had not happened that they had an opportunity to see a rainbow, one afternoon, in company with Miss Mary, under somewhat extraordinary circumstances. The occurrence was as follows: —

One afternoon, when Lucy had come to spend the day with Rollo, Rollo's father said that Jonas might take Rollo, Lucy, and Nathan, to ride in the carryall. They were very much pleased with the plan. They did not wait to have the carryall brought to the door, but they went out to the yard in front of the carryall-house, and got into it while Jonas was harnessing the horse.

Rollo took his place on the front seat, saying that he meant to ask Jonas to let him

drive part of the way. Lucy helped Nathan in behind, and then she got in herself. When they had got in, they found that they did not occupy nearly all of the space upon the back seat. Nathan was quite small, and Lucy was not very large, so that they both together did not need much more than half of the seat. Lucy therefore told Rollo that there was room for somebody else to go, and, after some discussion on the subject, they concluded to stop at the front door, and ask their father to let them go and invite Miss Mary to take a ride with them.

Rollo's father consented very readily, especially after he had looked into the carryall, and saw how much room was left on the back seat, when Lucy and Nathan sat close together. When they arrived at Miss Mary's house, and gave her the invitation, she seemed very much pleased, and she said that she would be ready in a very few minutes. So they waited at the door until she was ready, and then the whole party drove away.

They had a very pleasant ride, and they spent half an hour in climbing about some rocks on the shady side of a hill, gathering

flowers. There was a little spring which came out of a chasm in the rocks about half way up the hill, and here Miss Mary and the children sat down to eat their luncheon Generally, on such expeditions, the children took something to eat, and a little dipper to dip up water with from the brooks and springs, to drink. After their luncheon, they clambered down the rocks, and got into the carryall again to go home.

They undertook to go home by a new way, which led through an unfrequented part of the country. It was upon a road which was not much travelled, and for nearly two miles there was no house. Just before they entered upon this unfrequented part of the road, they saw in the western part of the sky, which was directly before them, some large and rounded clouds. The clouds were in full view, for they were riding towards the west.

"Jonas," said Rollo, "there is going to be a thunder shower."

"I think it very probable," said Jonas. "Those clouds look like a thunder shower."

"Yes," said Rollo, "only I don't hear any thunder.

"The clouds don't rise very fast," said Rollo.

"No," said Jonas; "I suppose they don't rise at all."

"Yes, Jonas," said Rollo; "they are higher than they were a little while ago, and presently they will be away up in the sky."

"How many degrees high are the tops of them now?" said Miss Mary.

"Let me see," said Lucy; and she looked earnestly forward over Rollo's shoulder. Lucy judged that the highest tops of the clouds were about a quarter part of the way from the horizon to the zenith.

"That," said she, "would be a quarter of ninety degrees. How much is a quarter of ninety, Miss Mary?"

"Cannot you calculate it?" said Miss Mary.

"Why, a quarter of eighty would be twenty," said Lucy; "and I don't think the clouds are quite a quarter of the way up, and so we'll call them twenty degrees high."

"Yes," said Miss Mary, "I should think that they were about twenty degrees high. When they are half way up the sky, they will be forty-five degrees high. I suppose

there will not be much danger of rain until they are more than forty-five degrees high."

"But, Jonas," said Rollo, "you said that they are not rising at all."

"I thought they were not," said Jonas, "but Miss Mary knows best."

"But what made you think they were not rising at all?" asked Rollo.

"Why, your father told us," said Jonas, "that the surface of the clouds was not really arched, but flat and level, and that the appearance of the dome was an illusion. Now, if that is so, then the clouds that appear to be rising in the west, must be really not rising, but only moving along towards us on a flat."

"Yes," said Miss Mary, "that is right. The clouds are, indeed, only moving along towards us on a level, or at least on what is very nearly a level. Their rising is only apparent. Of course, when any thing is moving along towards us, since it grows larger and larger in appearance as it approaches, the top of it must appear to rise."

"Then the clouds are not really rising?"

"No," said Miss Mary, "only *approaching*."

"Then," said Lucy, "what do you mean by saying that now they are twenty degrees high, and presently they will be forty-five degrees high?"

"Why, I mean that now they *appear to be* twenty degrees high, and that by and by they will appear to be forty-five degrees high."

"But I don't see what good it does to know that."

"Why, that is the nature of degrees," said Miss Mary. "Degrees and minutes are the measures of appearances, not of realities."

"I did not know that," said Lucy.

"Yes," said Miss Mary. "The sun and the moon, measured in degrees, are equal; that is, they are both about half a degree in diameter. But measured in reality, the sun is a great many hundred thousand times the largest. So that the half degree only measures the appearance.

"But remember," continued Miss Mary, "I do not say that degrees never measure any thing but appearances. Sometimes they are employed to measure realities; but when they are employed to measure distances and magnitudes in the sky, it is apparent dis-

tances and magnitudes that they measure So, when we use degrees to measure the rising of the clouds, it is only the apparent rising that we measure."

"There, Jonas," said Rollo, "here comes the last house."

Rollo pointed to a small house before them down the valley. It was the last house before they came upon the two miles, which were without any habitation.

"Yes," said Jonas, "and if I thought that we should not have time to get through the two miles before the shower, it would be best to stop here; for the wind will blow the rain directly into the carryall."

"Well, Jonas," said Miss Mary, "do you think that we can get through?"

"Yes, I think so," said Jonas; "the clouds rise very slowly."

Clouds always appear to rise very slowly at first, because, although they may be really advancing with great speed, their motion does not produce so great an effect upon their apparent elevation, as the same progress would when they were nearer. While the conversation above described had been taking place, the clouds had come on towards the

children many miles; and, besides, the party in the carryall were going rapidly towards the clouds. But still the clouds were so far off that no great effect was yet produced upon their apparent elevation. Lucy thought that now the upper edge of the clouds might, perhaps, be thirty degrees above the horizon.

"I *think* we shall have time to get home," said Jonas. "You had better give me the reins, now, Rollo, and let me drive, for I can drive faster."

Jonas's estimate of the distance which they had to go, compared with the time which would probably elapse before the shower would come on, was very correct; and the party would doubtless have had time to reach home before the shower, had not an unexpected cause of delay intervened. After passing the house which Rollo had referred to, they ascended a hill, and then, turning round a corner, they entered a wood, and drove on nearly a mile, when they saw a large, loaded wagon in the road before them, which seemed to be tipped down upon one side, as if it was in some difficulty. There was a man apparently at work about it, but

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corner of the wagon, which had been supported by that wheel, down to the ground. It would be impossible for one person to put the wheel on again alone; for it would require one to hold up the corner of the wagon, and another to put the wheel on. The man said that, if Jonas would stop and help him a few minutes, they could remedy the difficulty; but, if Jonas went on, perhaps no other person would come along that night, for it was a very unfrequented road. Still the man said that he should be very sorry to detain them, and so cause the lady and the children to get wet.

"Never mind that," said Miss Mary; "we shall not get wet much."

Just then a low, rumbling sound of thunder passed along the western sky.

"There! it begins to thunder already," said Lucy.

"Never mind," said Miss Mary. "They will get the wheel on very soon, I presume."

So Jonas got out, and began to assist the man. It took more time than they had expected; for, as the wagon was, of course, altogether too heavy for Jonas to lift it by a direct exertion of his strength, they had to

get a pry, and also some short logs to block up under the axletree as fast as they got it raised. The man cut the pry, and the logs for the blocks, out of the woods; and, as soon as they got the pry under, Jonas and Rollo bore on upon the outer end of it, so as to raise the axletree from the ground. The man put one of his logs under it, and then they placed the pry again, so as to get a new hold, and thus raise it a little farther. By this means, they gradually got it up so that the man put the wheel on. Then he and Jonas threw the pry and the blocks out of the road, and all were ready to move on.

In the mean time, the cloud had risen so that now the upper edge was quite forty-five degrees above the horizon, and it was rising still higher very rapidly. The wind began to blow too; and there was a constant thundering all around that part of the sky.

QUESTIONS.

How came Miss Mary to take a ride with the children? How were they all seated in the carryall? What appearances in the sky attracted their attention as they were coming home? How high was the upper edge of the

clouds when they were first observed? Repeat the conversation in regard to the apparent rising of the clouds. How did Jonas reason, to show that the clouds were not really rising? Was his reasoning correct? What calculation did Lucy make when she observed that the upper edge of the clouds was about one quarter of the way from the horizon to the zenith? What circumstance delayed them on their way home? How did Jonas and the wagoner manage to raise the axletree?

CHAPTER VI.

THE MOVING RAINBOW.

Miss Mary proposed that Rollo should get in behind with her and the other children, and, if it should begin to rain before they could get home, he would be in less danger of getting wet. Rollo said that he did not care if he did get wet; and he wanted to remain where he was, with Jonas; but Miss Mary said that she wished very much that he would come behind; and he accordingly yielded. Jonas also put the curtains all down, and buttoned them snug. He said that, unless the wind should blow very hard, he thought that they would not get wet behind, but he had no doubt but that the shower would come on before they could get home.

"And suppose the wind should blow very hard," said Rollo; "what shall we do then?"

"Why, then," said Jonas, "I suppose the best thing I can do will be to back against it."

Lucy did not know what Jonas meant by backing against it; and she was just going to ask him, when suddenly a pretty loud clap of thunder burst from the cloud at a higher elevation than any which she had heard before. She thought that it must have come from a part of the cloud as much as sixty degrees from the horizon, for it seemed to be about two thirds of the way from the horizon to the zenith; and Lucy recollected that the whole number of degrees between the horizon and the zenith was ninety, and, of course, two thirds of the elevation would be represented by sixty. The thunder frightened her a little, and the fright and the calculation of the altitude, which almost spontaneously passed through her mind, made her forget to ask Jonas what he meant by backing against the wind and rain.

However, she soon had occasion to learn without asking; for, as they were ascending a hill where the road was bounded on the side by trees, so that it was somewhat sheltered it began to rain a little. The foremost edge of the cloud was now so near the zenith that Miss Mary and the children, who sat in the back part of the carryall, could not see it

at all. The whole of that part of the sky which was visible from where they sat, was covered with one great expanse of dark cloud. They could see occasional flashes of lightning beaming over the whole of it; and now and then a zigzag chain of glistening light darted along from one side to the other. As they ascended the hill towards the summit, the wind began to blow somewhat fresher, and large drops of rain began to fall; and, when they reached the top, a very sublime spectacle was awaiting them upon the other side. The roads were filled with clouds of dust rising and driving on towards them with great speed. The tops of the trees were bending and roaring under the tempest, and the streams of rain were very visible a short distance before them, falling from the clouds. In short, it was very manifest that there was a great tempest of dust, wind, and rain, close at hand, and coming upon them in all fury.

At the top of the hill where they first obtained a view of this scene, the road happened, very fortunately, to be broad and level Jonas, without saying a word, took a wide sweep, and turned round, and before

the children had time to recover from their surprise, or to ask him where he was going, his horse was trotting fast down the hill.

"Why, Jonas," said Lucy, "what are you going to do?"

"I am only going down the hill a little way," said Jonas, "where we shall be sheltered a little; and there we shall have to stop till the shower blows over. With the back of the carryall to the wind, we shall not get wet."

In a few minutes Jonas stopped. The spot where he stopped was a little level place in the road, below the first pitch in descending the hill. He had hardly reined up his horse before the tempest came upon them in all its fury. The wind roared among the trees, and whistled by the sides of the carryall, and then a great puff of dust, leaves, and sticks, came sweeping by them, and sailed away down the hill, filling up the whole roadway, and cutting off the whole view of the country below. Then came the rain, driving against the sides and back of the carryall, and showering upon the leaves of the forest. The dusty road was first spotted with the drops; a moment after-

wards, it was drenched with water; and little streams soon filled the ruts and lines of depression, and ran swiftly down the hill. There were several bright flashes of lightning, and the thunder rolled all over the heavens. But, notwithstanding all this tempest coming behind them, before them, in the east, was a broad belt of clear blue sky; for the cloud had only advanced about thirty degrees beyond the zenith, so that from its foremost edge, down to the eastern horizon, — towards which, since Jonas had turned the carryall round, their faces had been directed, — there was a space of about sixty degrees which looked clear and serene.

The first onset of the tempest was the most violent, and it soon abated in some degree; but it did not abate a great deal. It settled into a steady rain, accompanied by wind, which Jonas knew would have driven the rain into every part of the carryall, if they had attempted to face it. It did not, however, wet them at all, as they were. Jonas drew up a leather boot, which was attached to the dasher in front of the carryall, over his knees, so that he was protected from what little rain

fell upon that part of the vehicle which was not covered by the top. The horse, however, had no shelter, and the rain ran down his sides, and poured off from every descending point of his harness in streams.

They remained in this situation for nearly three quarters of an hour; and then, when Jonas put his head out at one side of the carryall to look back, in order to see what the appearance of the sky was in the west, behind them, he said that it was breaking away, and that fair weather was coming again. A part of the cloud, however, was still over their heads, so that it continued to rain; and in the east, where the sky had been clear and serene when they first turned round, there was now a broad expanse of dark cloud extending down to the horizon. When the shower was coming on, the west was dark, and the east was clear. Now, the condition of the sky was reversed; the east was black and gloomy, and the west was clear.

In fact, the brightness which now beamed from the western sky was beginning to surpass altogether that which had appeared in the east; for the sun was in that quarter of the heavens, and the children, though they

were seated in the back part of the carryall, where they could not see the western sky, were still animated and cheered by seeing the trees on each side of the road brighten up as the sky brightened behind them; and at last there suddenly burst forth a flood of sunlight, gilding the whole forest, and lightening up the distant hills.

The rain had now nearly ceased, and Jonas thought that they might try to go home. He accordingly turned the horse round, and they drove up the hill. When they came upon the broad, flat place at the top, where he had turned at first, the rain began to drive into the carryall again, and Miss Mary said that, as they had waited so long, and kept themselves dry, it was not wise to get wet now, just to save a few minutes; and so she proposed to Jonas to turn again, at least to one side, and so wait a few minutes longer.

Jonas accordingly turned the horse to one side of the road, and then backed the carryall to the other; and, as the rain still came in, he concluded to move entirely round, so as to face the east again; though he said that it would not be necessary to go down the hill. As he turned the horse towards the east, so as

to bring the eastern sky again into view, the delight and surprise of the children were suddenly awakened at the spectacle of a magnificent rainbow, which shone out with the greatest brilliancy from the dark mass of clouds.

"O, what a beautiful rainbow!" said all the children.

"Yes," said Miss Mary; "that is because the sun shines bright, and there are a great many drops of rain."

"And you promised, Miss Mary," said Lucy, "to tell us something about the rainbow."

"Yes," said Rollo; "you told us that it was an optical illusion."

"I am not certain," said Miss Mary, "that I ought to call it an optical illusion, or not; but there are certainly several illusions about it."

"What?" asked Rollo.

"Why, in the first place, it is not nearly as far off as we imagine. Children generally think it is a great way off against the sky, or where they suppose the sky to be; but the colors come really from the drops which are nearest to us, and falling from the clouds too.'

"How do you know?" said Lucy.

"Why, we know in this way," replied Miss Mary. "Whenever there is any rain falling between us and the hills off at a little distance from us, we see the rainbow continued down this side of the hills. Sometimes the lower ends of the rainbow come before trees or houses, so that we can see the trees or the houses through the colors."

"Yes," said Lucy; "we can now."

The children all looked at the lower extremities of the rainbow before them. They were both continued down below the horizon; and one of them was extended so low that several objects in the landscape could be seen through it.

"See," said Lucy, pointing to the place, "that end of the rainbow comes down this side of that great gate. I can see the gate through it."

"Yes," said Miss Mary; "that proves that the colors which we see, come from drops of rain falling between us and the gate, which is not very far from us, — much nearer than most persons imagine the rainbow to be. So that is one illusion. But there is another greater than that. We are all looking pretty nearly in the same direc-

I CAN SEE THE GATE THROUGH THE RAINBOW.—Page 86.

tion, and we think that we are looking at the same rainbow; but it is in fact four different rainbows that we are looking at."

"O Miss Mary," said the children, "four rainbows!"

"Yes," said Miss Mary. "The rainbow which each one of us sees, is a little different from the one which the others see. I can prove it if Jonas will drive on a little until he gets to the other side of the road."

Jonas immediately made the horse move along. It happened that the grass at the side was level with the roadway here, so that the horse went on until he came to the stone wall, and then he stopped. The children all the time watched the rainbow.

They found that the ends of the curve of colors moved with them. The extremities which had appeared to come down over the gate slowly moved off from it in the same direction with that in which the carryall moved, so that now they saw a tree through the rainbow instead of a gate. The horse had gone towards the north in crossing the road, and the tree stood at the north of the gate, so that the rainbow had moved in the same direction with the carryall.

"Now," continued Miss Mary, "suppose Rollo were to go back where we were at first, and Lucy remain here, — you perceive that Rollo's rainbow would come down over the gate, while the one which Lucy would see would come down over the tree; so that the rainbow which Lucy would see would be a little to the north of the one which Rollo would see."

"Yes; but, Miss Mary," said Lucy, "we were all together when you said that we saw four different rainbows."

"Your eyes were not all together."

"Pretty nearly," said Lucy.

"Then your four rainbows would be pretty near together, but they would not be the same. Every body, wherever he stands, sees a rainbow exactly opposite to himself from the sun; that is, the centre of the curve of the rainbow is exactly opposite to his eye. Now, no two persons' eyes can be in exactly the same place, and of course the opposites cannot be exactly the same; so that every person's rainbow is different from every other person's."

"O Miss Mary!" said Rollo. "Then there must be ten thousand rainbows in the sky."

"No," said Miss Mary; "there are no rainbows at all."

"O Miss Mary!" exclaimed the children. They thought that this assertion was absolutely incredible. As for Jonas, he did not say any thing, but he was convinced that all which Miss Mary had already explained must be true; and so he had no doubt that she would be able to establish this last assertion. However, by this time the rain had almost entirely ceased; and so he backed the horse into the road again, and then turned on the way towards home.

QUESTIONS.

What precaution was adopted to prevent Rollo from getting wet? Describe the appearances which they observed when they ascended the hill just before the shower came on. What did Jonas do in this emergency? Describe the appearances when the shower came on. How long did they have to remain in this situation? What caused them to stop at the top of the hill the second time? What was the first illusion which Miss Mary mentioned in respect to the rainbow? How did she prove that different persons see different rainbows? What extraordinary statement did she make at last?

CHAPTER VII.

THE DEW-DROP.

They rode a short distance in silence, admiring the freshness and beauty which the whole landscape exhibited after the shower. After a pause of some moments, Rollo said,—

"I'm sure I don't understand how we can see so many rainbows in the sky, and yet there be none there."

"It does appear rather paradoxical, I confess," said Miss Mary.

"Paradoxical!" repeated Lucy. "What does that mean?"

"Any thing that is apparently contradictory or impossible is said to be paradoxical," replied Miss Mary.

"I think that this is *really* impossible," said Lucy.

"I suppose it must seem so to you," replied Miss Mary; "and I don't suppose that I shall be able to satisfy your minds about it.

but what I said is true, notwithstanding. At least I have no doubt of it myself."

"Why, how can we possibly see so many rainbows in the sky," said Rollo, "unless there are some there?"

"There is nothing in the sky, or rather in the air, but the drops of rain," replied Miss Mary. "Every drop of rain reflects the rays of the sun in such a manner as to produce a number of colors. When we stand in a certain position, we see these colors. If there was only one drop of rain in the sky, and the sun was shining on it, it would produce colors. But then the rays of colors would not all go off from the drop together. The red rays would go off in one direction, and the orange rays in another, and the yellow rays in another, and the violet in another, and so on with them all.

"So you perceive," continued Miss Mary, "we could not see all these colors from one drop at the same time. If we were to hold our eye where the violet rays come, then the drop would look of a violet color. If we then move our eyes to the place where the blue rays come, then the drop would look blue; and so with all the other colors. By

moving our eye along, we should make the colors change. This is so not only with drops of rain, but with any drop of water. I suppose you have often seen it in dew-drops."

"Yes," said Rollo; "Nathan found one the other morning in the garden. Don't you remember, Nathan?"

The incident to which Rollo referred was this: One morning, several days before this ride, Nathan went out to play upon the platform behind the house. The grass was wet with the morning dew, and so he did not go out into the yard, but remained upon the platform, building fences for a farm with little sticks. Presently he concluded that he would have a stone wall around one of the fields upon his farm, and he wanted Rollo to bring him some little stones. Rollc told him that he thought that he could get the stones himself; but Nathan said that he could not go off the platform, because the ground was so wet that he should wet his shoes.

Then Rollo told him that, if he stepped down from the platform to the walk, where there was no grass, he would not wet his shoes, and that he might get little gravel-

stones from the walk and build his wall with them. Rollo was himself cutting wood with his little axe in the shed, and so he did not want to come and play with Nathan.

Rollo cut wood for about a quarter of an hour, and then he began to be tired; and so he came back to see what had become of Nathan.

He found him standing at some distance from the platform, on the edge of the gravel-walk, looking over very intently at something down among the grass.

"Nathan," said Rollo.

"What?" said Nathan.

"What are you looking at?"

"Come here, Rollo," said Nathan.

Rollo ran across the platform to the gravel-walk, and thence along the walk to where Nathan was.

"What is it, Nathan?" said he, looking down at the same time to the place to which Nathan's eyes were directed.

"I saw a beautiful thing down here in the grass," said Nathan; "and now I can't find it."

"What kind of a thing was it?" said Rollo.

"O, it was a very beautiful thing indeed."

"What did it look like?" asked Rollo.

"I don't know," said Nathan, "only it was very beautiful. I guess it was a diamond."

"Where was it?" said Rollo.

Nathan pointed to the place. "There, Rollo," said he, "it was right there among the grass. If you would step over there, and just push the grass away a little, you could find it; — only you must give it to me."

Rollo took a long stick, and poked about among the grass for some minutes, but without any success. He thought that Nathan must be mistaken; but Nathan was very positive that he saw it, and that it was a very beautiful thing indeed; and, while they were wondering what it could be, and what could have become of it, they heard their mother's voice at the window, saying, —

"Children, don't go upon the wet grass."

"No, mother," said Nathan, looking down at his feet to see that they were kept within the limits of the walk, and were not upon the grass at all. "No, mother, we are not on the grass."

"What are you doing?" said their mother.

"Why, mother," said Rollo, "Nathan saw something beautiful in the grass here, and we can't find it. I wish that you would come out and find it for us."

So Rollo's mother came out upon the platform, and walked along the gravel-walk to the place where the children were standing.

"What did it look like, Nathan?" said she.

"It looked very bright," said Nathan.

"What shape was it?" asked his mother

"I don't know," replied Nathan. "I could not see the shape very well."

"What color was it, then?" said his mother.

"Why, it was blue," said Nathan — "or else red. I believe it was a little red."

Nathan's mother looked about the yard a minute, and presently she drew Nathan up close to her, until she got his eye very near to where her eye was, and then pointed to a place in the grass several yards from where they were standing, and said, —

"Look exactly there, where I am pointing, and see if you cannot see another one, just like it."

Nathan looked very intently in the direction to which his mother pointed, and then he exclaimed, —

"O, yes, there is another! Go and get it Rollo."

"It is only a dew-drop," said his mother.

"A dew-drop," said Rollo.

"Yes," replied his mother, "a dew-drop, reflecting the rays of the sun, so that, when you hold your eye in a particular position, you see the bright colors in it. But if you move your eye a little way, the colors all disappear."

"Why do they?" said Rollo.

"Because," said his mother, "the rays of colors only come off from the dew-drop in one direction; and, if you move your eye out of the range in which they come, you lose them, of course."

So Rollo's mother let Rollo and Nathan try the experiment of moving their heads one way and the other, and they found that the colors disappeared. She explained to them also the reason why Nathan could not find his first dew-drop. When he stood on the platform, she said, his eye happened to be in the range of the red or blue rays coming

from the drop; but, in advancing along the walk, his eye got out of the range again, so that he lost all the brilliant colors; and, if he had seen the drop at all, he would only have seen it as a common drop of water.

Rollo and Nathan were very much interested in this explanation; and, after their mother had gone in again, they amused themselves, for some time, in finding such drops in various parts of the yard, and in making the colors appear and disappear at pleasure by moving their heads into and out of the range of the colored rays.

Now, when Miss Mary alluded to the dew-drops, in her conversation with the children in the carryall, Rollo and Nathan immediately recollected the circumstance above described, and they told Lucy and Miss Mary the whole story. Miss Mary said it illustrated exactly what she meant. "Every one of the drops of rain in the sky," said she, "is like a dew-drop. It reflects the colors, only you do not see the colors unless your eye is in exactly the right position. That is the case with all the drops in the air which the sun shines upon. The drops in the red part of the rainbow, are really no more red than those in

the dark cloud beyond the rainbow; only they happen to be in such a place that the red-colored rays that are reflected from them come to our eye. If we move along a little, we get out of the red rays of these drops, and get the eyes into the red rays of some other drops; so that you see there are no real curves of colors in the sky, but all the drops, all over the surface of the clouds, reflect many colors, and some of these colors come to our eyes, and some do not."

"But I don't see what makes the shape of a curve, then, in the rainbow," said Lucy.

"That is very difficult to understand," said Miss Mary.

"I wish you would try to explain it to us," said Lucy.

"Well, I will try," replied Miss Mary, "but I don't expect to succeed. First, I must tell you what the centre of the rainbow is. A rainbow is not generally so large as half a circle; but suppose it was continued in the same curve till it was made a complete circle, then the centre of the circle would be the centre of he rainbow Do you understand that?"

The children said they did understand that.

"Now, the centre of the rainbow," continued Miss Mary, "is always exactly opposite to our eyes from the sun. That is, if we imagine a line to be drawn from the sun in the west, straight to where our eye is placed, and then to be continued on to the east, it would pass through the centre of the rainbow. Of course, if the sun is above the horizon ten degrees, the centre of the rainbow will be just as far below the horizon."

"That is, ten degrees," said Rollo.

"Yes," said Miss Mary; "and that would make the rainbow rather low; for the middle of it would be below the horizon.

"And if the sun is only five degrees above the horizon, then the centre of the rainbow would be — where?" asked Miss Mary.

"Five degrees below," said Rollo and Lucy.

"And that would make the rainbow higher," said Miss Mary. "Now, if the sun was exactly at the horizon in the west, then the rainbow would be exactly at the horizon in the east, and that would make the rainbow higher still; for, if the centre of it was in

the horizon, half of the rainbow circle would be above the horizon, which would carry the upper part of the curve very high in the sky. So you see the lower the sun is, the higher the rainbow is.

"Now," continued Miss Mary, "suppose there should be a rainbow early in the afternoon, — would it be a high rainbow, or a low one?"

"A low one," said the children.

"And if there was a rainbow just at sunset, would it be a high or a low one?"

"A high one," said the children.

"And in the middle of the day there cannot be a rainbow," said Miss Mary, "because then the sun is over our heads; and the centre of the rainbow would be under our feet, where there could be no clouds or drops of rain to reflect the colors."

Just at this time, the party arrived at the place where the road turned off to the house where Miss Mary lived; and in a few minutes more, they were at her door. They wanted very much for her to explain to them why there was such an appearance of curves, when the whole sky was covered with drops which all alike reflected the

colors; but she said that she should not then have time to do it.

"It is better to wait," said she. "I shall see you all again one of these days. You understand pretty well what I have explained. Now, you have only got to remember that; and also remember what the point is that you do not understand, so as to have the line distinct between what you do know, and what you do not know. You do know that every drop which the sun shines upon, as it falls through the air, reflects the colors in certain directions, and that, if we put our heads in the right place, we shall see the colors. But you do not understand why it is, that, of all the drops in the sky, we only see the colors of those that happen to be in the curve of the rainbow.

"Why," said Miss Mary, after she had finished these remarks, "here's Nathan, scund asleep."

It was true. Nathan, who was altogether too young to understand such abstruse discussions, had laid his head back against Miss Mary's arm, and had gone to sleep. He was not, however, to blame for inattention. He tried to understand what Miss Mary said

but he could not. The philosophy of the rainbow was a subject beyond his years. So he had lost himself, and sunk down into slumber soon after Rollo had finished the account of their hunt for the dew-drops in the grass.

QUESTIONS.

Relate the story of Nathan and the dew-drop. Why was it that the dew-drop looked sometimes red and sometimes blue? How did Miss Mary say that this incident illustrated what she had been saying? What did Miss Mary mean by the centre of the rainbow? Where is the centre of the rainbow in respect to the sun? Will a rainbow just before sunset be a high or a low rainbow? How will it be when the rainbow appears in the middle of the afternoon? Can there be a rainbow at noon? Why not?

CHAPTER VIII.

POLES OF REVOLUTION.

One evening, late in the autumn, Rollo went out with Jonas to the barn, to ascertain what was the cause of a noise that Jonas had heard. He was afraid that one of the horses might be in some difficulty. The stars were very bright that night, and, on the way to the barn, Rollo began to look at a long range of what appeared to be thin clouds, which extended across the whole heavens. Jonas told him that it was not clouds, but stars.

"Stars!" exclaimed Rollo.

"Yes," said Jonas, "so thick together, and so small, that they make the appearance of a cloud." Jonas said that the whole was called the *galaxy*.

Rollo remained in the yard while Jonas went into the barn. After being absent a few minutes, Jonas returned, and found Rollo still looking at the galaxy.

"What a strange thing!" said Rollo.

"Yes," said Jonas, "but I think that the strangest thing in the sky, is something which is nothing at all."

"What do you mean by that?" said Rollo.

"Why, I think the strangest thing in the sky is the pole; and the pole is nothing at all."

"Where is it?" said Rollo.

"There," said Jonas; and so saying, he pointed to a part of the sky nearly over one corner of the barn.

"I don't see any thing there but stars," said Rollo.

"No," said Jonas; "I told you the pole was nothing."

"Isn't it any thing at all?" asked Rollo.

"No," replied Jonas, "nothing but a place."

"Then I suppose something remarkable happens there; don't there?" said Rollo.

"No," said Jonas; "there is no place in the sky where it is so unlikely that anv thing will happen, as there."

"A'n't there any stars there?" said Rollo.

'No." said Jonas, "not exactly there, and

no stars ever go there. The stars, in rising and setting, go pretty nearly over all the rest of the sky, but they never go there."

"How big is the pole?" said Rollo.

"It hasn't any bigness at all," said Jonas.

"Couldn't you see it through the telescope?" asked Rollo.

"No," said Jonas.

"Not through that monstrous great telescope that Mr. Herschel made?"

"No," said Jonas; "because there is nothing there to see."

"Then I don't see what good it does to have any pole," said Rollo.

Jonas laughed; and he and Rollo both went into the house.

Rollo went into the parlor, where he found his father sitting at a table. He had been reading aloud to Rollo's mother, who was sitting at her work. He was just shutting up his book when Rollo came in. Rollo related to his father and mother what Jonas had said about the pole. His father said that it was all true, though he did not see how Jonas knew any thing about it.

"I suppose," said Rollo, "that he read it out of some book."

"At any rate," replied Rollo's father "Jonas is correct; there is something very curious about a pole of revolution in all cases, though, as he says, in itself it is nothing at all."

"A pole of revolution?" repeated Rollo.

"Yes," replied his father; 'the pole in the heavens is a pole of revolution."

"But what do you mean, father, by a pole of revolution?"

"Let me see," replied his father. "Isn't there any way for me to illustrate it to you? If I could think of something which I could make revolve ——"

"Well, father, haven't you got a half a dollar in your pocket? If you have, you can make that whirl on a plate."

"That would not do very well," said his father.

"Then, father," said Rollo, "we might take an apple, and tie a string around the stem; and then we can twist the string, and so make the apple whirl."

"That would not do very well either," replied his father; "for then the pole of revolution would come in the stem."

"I don't know what that means," said Rollo.

'You will see by and by," replied his father. "I will take a book. I will try and see if I can make that whirl. Get me a book with printing on the cover."

So Rollo went to the book-closet to look for a book with printing on the cover. He found an Arithmetic, which had been bought for him to study. The back of the book was of some sort of leather, and the sides of the cover were of paper, with printing upon them. On one side, was the title of the book, and on the other, a multiplication table, and some other tables.

Mr. Holiday then took two pieces of twine, each about a yard long, and laid them down upon the table in such a manner that they crossed each other at right angles in the middle of the table, — the four ends extending out towards the four sides of the table. He then laid the book down upon the twines at the place of crossing. He then gathered up the four ends of the twine over the book, and, of course, he could lift the book up from the table. Then he adjusted the ends in such a manner that the book rested in a perfectly horizontal position.

"Now," said Mr. Holiday, "I must twist the string."

He accordingly let the book down upon the table again, so that it might be supported by the table, and kept at rest while he twisted the string formed by the four strands of twine. When he had it sufficiently twisted, he gently lifted the book from the table by the string, and held it so that Rollo could see it. It began to whirl round swiftly, in proportion as its weight caused the untwisting of the string.

"Now," said Mr. Holiday to Rollo, "you see that, as this book revolves, the outside parts must necessarily move the swiftest."

"Yes, sir," said Rollo.

"Because," continued Mr. Holiday, "the farther off any part of the book is from the centre, the farther it has to go round at every revolution; and of course it must move the faster."

"Yes, sir," said Rollo.

"So that those letters," continued his father, "which are near the top and bottom of the cover, move swiftly in large circles."

"Yes, sir," said Rollo; "and those that are

nearest the centre of the book go round in small circles."

"Those that are nearest the centre of the motion," said his father. "It may or it may not be exactly the centre of the book.

"There is the centre of the motion," continued his father, pointing to a place upon the upper side of the book.

Rollo observed that from the outer parts of the book, in towards the place to which his father pointed, the circles grew smaller and smaller, and exactly at the place were several letters which appeared very plain. It is true they turned round and round upon themselves, but they did not sweep round in great circles, like the letters farther off; and there was one letter — one that seemed to be very near the centre of motion — which Rollo could read almost as well as if the book had been at rest. It was an O. His father said that the centre of motion was very near that O.

"Now," said his father, after Rollo had looked at it a few minutes, "you can understand what a pole of revolution is. That centre of motion which you are looking for

is a pole. There is another pc
under side of the book."

"Let me see, sir," said Rollo.

So his father lifted the book as higl as he could, so as to let Rollo look upon the under side. Rollo said that there was just such a centre of motion on the under side.

"Yes," said his father, "and that is the other pole. The line running right through the book from one pole to the other, is the axis.

"Now," continued his father, "I can shift the poles of revolution by slipping the strings a little, so as to make the parts of the book revolve about a different centre; so that you see the axis and the poles are, in themselves, nothing, as Jonas said.

"Now, it makes no difference," continued his father, "whether the book revolves swiftly or slowly, in respect to the poles. You can see where the centre of motion is, when it revolves swiftly; but there would be such a centre just as really, if it revolved slowly. If the book only went round once in an hour, there would still be two poles of revolution; and so if it only went round

once in a day; only, in that case, it would be much more difficult to find it. When any thing is whirling round fast, we can see by the little circular lines, which grow smaller and smaller towards the centre, where the centre is. In a top, if it revolves in a true and steady manner, one pole is at the point which the top spins upon, and the other is just in the middle of the peg. So in an apple, when it revolves by a string around the stem, — the pole of revolution, on the upper side, is generally just on one side of the stem."

"Why not in the middle of the stem?" said Rollo.

"Why, the apple," replied his father, "usually hangs a little over to one side, because the string must necessarily be tied in a knot on one side; so that you will generally see the end of the stem revolving itself in a little circle; and the pole is just in the centre of that circle."

"I mean to look," said Rollo, "the next time I have an apple to roast."

"And so," continued his father, "whenever you throw your ball through the air, you make it revolve as it passes along. So

a ball has its axis of rotation, and its two poles."

"Of rotation?" said Rollo.

"Yes, or revolution. *Rotation* means the same as *revolution*. Sometimes they call it the axis of *rotation*, and sometimes the axis of *revolution*. Every thing that revolves must revolve around an axis of rotation; even a half dollar whirling on its edge upon a plate."

"Let us try, father," said Rollo; "and let me see if I can find it."

"You can see where the upper pole is," replied his father. "The lower pole will be where the half dollar rests upon the plate; and the upper pole will be in the upper part of the edge. The axis will run down through the middle of the silver from one pole to the other."

Rollo wanted to go and get a plate, but his father said that he could whirl the coin upon the table just as well. Rollo could never whirl money himself, that way, upon the table, because he could not keep it from running off at the edge. But a plate, being higher at the edges, kept it in. He found, however, that his father could whirl it upon

the table without difficulty; and Rollo could see very distinctly that the upper pole of its rotation was within the edge of the coin.

"Now," said Mr. Holiday, after Rollo had amused himself for some time looking at the curious appearances exhibited by the piece of money, "the whole sky is all the time revolving. It moves slowly, — the sun, moon, and stars, all together. The various parts come up successively in the east, pass over, and go down in the west. It takes twenty-four hours for one revolution. If the revolutions were very quick, for instance, a hundred in a minute, the stars would shoot round so swiftly that they would make bright circles in the sky, just as the letters of ink, on the book, made dark circles; and then, by going out and looking, we should see at once where one of the poles of the revolution was; for we should see the stars go round and round that pole, in circles smaller and smaller, the nearer they were to it.

"But," continued Mr. Holiday, "the stars move so slowly that we cannot see at once where the centre of motion is; by watching them a long time, however, we can find out. The astronomers have found out where the

centres of motion are. One of them is up in our sky, where we can see it; the other is down out of sight, so that we cannot see it, in this part of the world. The pole which we can see from this part of the earth, is called the *north pole.* So now you know what the pole is, which Jonas meant. It is nothing in itself. It is only a centre of the motions of other things."

"A'n't there any stars there?" asked Rollo.

"No," said his father. "There is one star very near, which of course goes round the pole in a very small circle, like the stem of the apple whirling."

"What is the name of that star?" asked Rollo.

"Cynosura," replied his father.

"Cynosura," repeated Rollo.

"Yes," said his father; "but then people generally call it the *North Star*, because it is so near the northern pole."

QUESTIONS.

What were the circumstances which led Rollo and Jonas to talk about the pole? What was the remark which Jonas made first about it? What questions did Rollo ask

about the pole? What were Jonas's answers? By what name did Rollo's father call the pole? How did he propose to illustrate it? What things did Rollo propose to use? What plan did Rollo's father at last adopt? Describe how he contrived to make the book revolve. What appearances did he point out to Rollo while the book was revolving? Did Rollo see where the pole was? How did he know where it was? How many poles were there? Where was the other one? What is the axis? What did Mr. Holiday say about shifting the place of the poles and the axis? What other word means the same as *revolution*? What did Mr. Holiday say at last about the pole in the heavens?

CHAPTER IX.

RESPONSIBILITY.

Some days after the conversation related in the last chapter, Nathan was playing in the green lane behind his father's house, and he found Rollo seated upon the grass by the side of his little wheelbarrow, very intently examining something about the wheel.

"Rollo," said Nathan, "what are you doing?"

Rollo did not answer.

"Rollo," repeated Nathan, calling louder than before, "what are you looking at?"

The fact was, that Rollo had observed that the wheel of his wheelbarrow was a revolving body, and he was endeavoring to find the poles of its revolution. He was so intent upon his observations that he paid no attention to Nathan's calls. So Nathan ran to see what he was doing.

Rollo contrived to lean the wheelbarrow over a little to one side, so as to free the

ROLLO FOUND SEATED BY HIS WHEELBARROW.—Page 118.

wheel from the grass, and then he could whirl it quite swiftly by taking hold of one of the spokes. Nathan stood by, with his hands behind him, looking on very intently.

"What are you trying to do, Rollo?" said he.

"Why, I want to find the poles," said Rollo.

"I don't understand what you mean," said Nathan.

"No," said Rollo; "you are not big enough to understand."

Here Rollo whirled the wheel of the wheelbarrow again.

"How swift it whirls round!" said Nathan.

"I believe the pole is right in there," said Rollo, pointing to the end of the iron gudgeon on which the axle of the wheel revolved. The wooden bar which passes through the centre of the wheel, is called the *axle*, or the *axletree*. In the ends of this axle are small irons on which the axle turns. These irons are called *gudgeons*. There are two sockets, generally made of iron, in the ends of the two sides of the wheelbarrow, in which the gudgeons play. These sockets are called the *boxes*. Almost all wheels that are con-

structed like the wheel of a wheelbarrow, revolve by means of gudgeons and boxes.

Nathan looked very intently into the end of the iron gudgeon.

"I don't see," said Nathan.

"Never mind," said Rollo. "I'm going to wheel my wheelbarrow along now."

"No," said Nathan; "let me whirl the wheel a little first."

"Well," said Rollo, "I'll walk towards home, and you may wheel my wheelbarrow along, when you have done."

"Well," said Nathan.

So Nathan sat down upon the grass, and began to whirl the wheel, and Rollo sauntered along towards home.

About half an hour after this, when it was nearly dark, Rollo and Nathan came together into the shed where Jonas was at work splitting a little wood. As they came in at the door, Rollo was saying to Nathan, "We'll leave it to Jonas, Nathan."

"Jonas," said Rollo, when they had got pretty near to him.

"Stand back a little," said Jonas, 'out of the way of my axe."

"Jonas,' repeated Rollo, "mustn t Nathan

go and get my wheelbarrow? I lent it to him, and so he promised that he would wheel it in for me."

"No," interrupted Nathan, "I ——"

"Stop," said Jonas to Nathan; "don't interrupt Rollo. Let him tell his story through from beginning to end; then I'll hear you."

"That's all," said Rollo, "only he won't bring it in."

"Well, now, Nathan," said Jonas, "give your account of it."

"Why, Jonas," — said Nathan, — "you see, — why, — I didn't promise him at all. I only wanted to whirl the wheel a little, and then I wanted him to wheel it in. Besides, I was afraid that I could not catch him."

These statements were quite insufficient to give Jonas any thing like a clear and correct account of the case. However, by questioning the boys more fully, he at last understood the transaction. It seems that Nathan had continued to play with the wheel until he found that Rollo had gone so far towards home that he was afraid of being left alone, and so he left the wheelbarrow, and ran after him. Rollo, who was then just climbing upon the gate, insisted that he should go

back after the wheelbarrow, and wheel it along with him. But Nathan would not So they had both returned to the house without it. After a time, Rollo, feeling uneasy at the prospect of leaving his wheelbarrow out all night, and not being able to persuade Nathan to go for it, had concluded to report the case to Jonas.

"Nathan's defence is," said Jonas, "that he did not absolutely promise to wheel the wheelbarrow back. But I don't think the defence is valid."

"Valid?" said Nathan; "what is *valid?*"

"Why, good," replied Jonas. "It is not a *sufficient* defence. You did not promise in words; but you took the wheelbarrow on the understanding that you were to wheel it home."

"No," said Nathan, "I didn't take it at all. It was lying right there on the ground."

"You took possession of it, I mean," said Jonas. "You took it under your charge."

'Yes," said Nathan.

"Suppose," continued Jonas, "I were to go to a shoemaker's shop, and ask him to make me a pair of shoes; and suppose he should measure me, and make the shoes, and,

when they were done, I should come and take them away. Then, afterwards, suppose he should come and ask me to pay for them. Ought I to pay him, or not?"

"To pay him," said Nathan.

"And suppose I should tell him that I did not *promise* to pay him, and that therefore I would not."

"Then," said Nathan, — after a moment's pause, during which he seemed to be considering what it was best to do in such an emergency, — "then I should think he had better take the shoes, and carry them home again."

"But shouldn't you think I ought to pay him?" asked Jonas.

"Yes," replied Nathan.

"Certainly," said Jonas, "because the promise was understood. So, when Rollo left the wheelbarrow with you, it was understood that you were to wheel it along when you had done spinning the wheel about. Therefore you ought to have done it."

"There," said Rollo, "I told him so, Jonas; but he said that I ought to wheel the wheelbarrow home."

"Very well," said Jonas; "he was right in that."

"Right!" exclaimed Rollo.

"Yes," said Jonas; "you ought to have wheeled up the wheelbarrow, most certainly."

"I?" said Rollo.

"Yes," said Jonas, "certainly."

"Why, Jonas," replied Rollo, "you just said that Nathan ought to."

"Yes, but he wouldn't," said Jonas.

"Well," said Rollo.

"Well," repeated Jonas.

"Why, if it was Nathan's duty to wheel it up, I don't see how it could be mine," said Rollo.

"The duty *devolved* upon you, when he refused to do it."

"Devolved," said Rollo.

"Yes," replied Jonas. "It very often happens that, when a duty belongs to one person alone, if he refuses to perform it, it then passes over to another person, who from that time is under obligation to perform it. This is a case of that kind. It was originally Nathan's duty to wheel up the

wheelbarrow; but, in the event of his refusing to perform it, the obligation devolved upon you.

"For example," said Jonas, "there were two boys, named James and John. Their father sent them one day to carry a basket with something in it to another house, about half a mile from where they lived. The basket was pretty heavy, and so he said that James must carry it half of the way, and John the other half. They went along till they got a little more than half way, and then James wanted John to carry it; but he wouldn't. He kept running about by the sides of the road, chasing butterflies."

"O, what a boy!" said Nathan.

"Now, it wouldn't be right, in such a case as that," continued Jonas, "for James to put the basket down, and leave it, saying that he had carried it his part of the way, and that was enough. If John wouldn't carry it at all, then the duty would devolve upon him. He ought not to leave his father's property exposed there in the road. He ought to carry it safely himself, and then report the case to his father, when he got home. So when you, Rollo, found that

Nathan would not bring the wheelbarrow home, you ought not to have left it there. The duty of bringing it home devolved upon you when he failed to perform it. So you both did wrong, and I think that you ought both to go together, and get the wheelbarrow now."

The boys were silent. They did not know what to say in reply to Jonas's arguments; but they did not want to go for the wheelbarrow.

"And if you *don't* go," said Jonas —— Here Jonas paused.

"Well," said Rollo, "what then?"

"Why, then the duty of bringing in the wheelbarrow will devolve upon me, and I shall have to go."

"Why?" said Rollo.

"Because," said Jonas, "it is my duty to see that none of the property is injured, or exposed to injury. And so, whenever you fail to take care of what belongs to you, I must take care of it."

"Let us all go together," said Rollo.

"No," said Jonas.

"Why, you say it is your duty, as well as ours"

"No," said Jonas; "I did not say it was my duty *as well as* yours; but it will be my duty when you refuse to do it. It isn't a joint obligation that I hold with you, but an obligation which will come wholly upon me, when you cast it off from yourselves. So that I have nothing to do until you refuse to go. Then I have the whole to do. The first thing is, therefore, for you to say whether you will go or not. I have no duty at all in the case until you refuse."

Rollo and Nathan stood silent, both looking very grave. At length Nathan said, in a timid voice, —

"Rollo, I rather think we had better go."

Rollo did not reply.

"If you conclude to go, I can offer to go with you; but then, in that case, I should go only as a volunteer. It would not be in the fulfilment of any obligation. On the other hand, if you say you are not going, and I conclude to go, and then you go with me, you will go as volunteers; you will not be fulfilling your duty by going in that way to accompany me, after having refused to go yourselves."

"Well, Jonas," said Rollo, "do you think

you should go with us as volunteer, if we should decide to go?"

"I can't tell you any thing about it," replied Jonas. "You must decide for yourselves, independently of that."

Finally Rollo and Nathan concluded to go; and then Jonas said that he would go with them as a volunteer. On their way there took place a conversation in respect to the stars, which is recorded in the next chapter.

QUESTIONS.

What was Rollo's object in examining his wheel, as related at the commencement of this chapter? How did he place his wheelbarrow so as to be able to turn the wheel easily? What is the axle? What is a gudgeon? What request did Nathan make when Rollo was ready to leave the wheelbarrow? Did Rollo accede to this request? With what understanding? What dispute arose out of this case? How did Rollo state the case to Jonas? What did Nathan say in his defence? What was Jonas's decision? Did he consider Nathan as really engaged to bring home the wheelbarrow? What was his supposition about the shoemaker, to illustrate it? What did he afterwards say about Rollo's duty? Repeat the story that he told to illustrate this. What was the final result of the dispute?

CHAPTER X

THE GREAT BEAR.

"JONAS," said Nathan, as they walked along towards the great gate which led to the pasture, where the wheelbarrow had been left, "what was it that the boys had in that basket that they were carrying?"

"What basket?" asked Jonas.

"The basket that James and John had to carry, — that you told us about just now."

"O, that is of no consequence," said Jonas. "You may imagine any thing you please in the basket."

"But I want to know what was really in it," said Nathan.

"Jonas," said Rollo, "do you know where the pole is?"

"What pole?" asked Jonas.

"Why, the pole in the sky. There is a pole in the sky; and all the stars go round it. Don't you remember you told me about

it? and father told me some more. There's a star named Cynosura close by it."

"I don't know any star named Cynosura," replied Jonas; "but there is the North Star. That is very near the pole."

So saying, Jonas pointed to a star about half way between the zenith and the horizon. Rollo and Nathan both looked at it very intently.

"Is the pole pretty near that star?" asked Rollo.

"Yes," replied Jonas.

"Is it above it, or below it?"

"I don't know," replied Jonas.

"Couldn't you find out by some of your books?"

"Yes," said Jonas, "perhaps I could find out in my Astronomy. But I can't tell by looking in the sky, the stars go so slow. It takes the stars a whole day to go round once. If they only went quick, we could see very easily. If the stars about the pole whirled round swiftly, then we could see where the centre of the motion is. That North Star would go round in a little circle, and the other stars, which are farther off from the pole, would go round in a larger circle."

Jonas then showed Rollo what he called the seven Pointers. They were seven stars arranged in a form which presented a resemblance to the outline of a dipper; and Jonas said that they were sometimes called the *Dipper*. Two of these stars, namely, the two which formed the side of the Dipper, opposite to the handle of the Dipper, pointed, as Jonas said, very nearly to the North Star; that is, a line drawn through them, and continued towards the north, would pass very near to the North Star.

"That is the reason that they are called *Pointers*," said Jonas.

"But only two of them point towards the North Star," replied Rollo, "and you said that all the seven were Pointers."

"Yes," said Jonas; "we should not know the two Pointers from any other stars in the sky about as far apart from each other, if it were not for the other five which make up the Dipper; so that all seven of them help us to find the North Star."

The Dipper, at the time that Jonas pointed it out to Rollo, was pretty near the horizon; and it was below the North Star, so that, at this time, the two Pointers pointed upwards

But Jonas explained to Rollo that the Dipper revolved continually about the pole, so that it was sometimes off upon one side of the pole, and sometimes upon the other; and sometimes, he said, it was up in the middle of the sky. In fact, upon a little reflection, Rollo perceived that, if the constellation really revolved about the pole, the Dipper must necessarily assume all these various positions in every revolution.

"The Dipper goes round," said Jonas, "once every twenty-four hours. If we come out here to-morrow evening, we shall find it pretty nearly where it is now; but, in the mean time, it will have been all around the pole, and so will have got back to its place again. If we were to come out to-morrow morning very early, before daybreak, we should find that it had gone nearly half round; and then, of course, it would be up high in the sky."

"I mean to get up and see," said Rollo.

Just as Rollo was expressing this determination, he happened to look towards the house, and he saw his father coming. His father had wondered where he and Nathan were, and had come out to look for them.

"Father," said Rollo when his father had come pretty near, "Jonas has been telling us about the stars. There's a constellation, father," he continued, pointing to the stars of which they had been speaking. "Do you know what that constellation is?"

"Part of Ursa Major," replied his father.

"Ursa Major?" repeated Rollo.

"Yes," replied his father.

"Jonas calls it the *Dipper*," said Rollo.

"Very likely," replied his father. "There are a great many things which have more than one name. That constellation has two. The farmers call it the *Dipper*, and the astronomers *Ursa Major*. That means, the *Great Bear*."

"I don't see that it looks like a bear," said Nathan.

"No," said his father, "there is not any resemblance excepting in the tail. The handle of the Dipper is the tail of the Bear; and that row of stars looks a little like a tail."

"What do they call it the *Great* Bear for, sir?" asked Nathan.

"Because," said his father, "it is very large. The Dipper only covers a very small part of him. His head is away off that way."

So Rollo's father pointed to the part of the sky where the head of the Great Bear was situated; and Nathan perceived that it was really very large.

"Besides," continued his father, "there is another Bear in the sky called the *Little Bear*, and this is called the *Great Bear* to distinguish him."

"Show us the Little Bear, father;" said Rollo.

"The Little Bear is close to the pole," said his father; and so saying, he pointed to the pole. "There is a little Dipper in the Little Bear, only the stars which make it are fainter. The handle of the Dipper runs in towards the pole. The North Star is the last star in the handle of the Dipper, and the last in the tail of the Little Bear."

The children were very much interested in looking at the two Dippers and the two Bears; and at length, after some further conversation, Mr. Holiday walked along towards the house, leaving Jonas and the boys to follow.

Rollo said that he meant to have a ride, and began to climb into the wheelbarrow intending that Jonas should wheel him.

"Stop," said Jonas; "get out a minute, while I put a cushion in."

So Rollo got out of the wheelbarrow again, and Jonas began to gather some tall brakes which grew near the path, and to strew them in the bottom of the wheelbarrow, so as to keep Rollo's clothes from being soiled by the wheelbarrow. Then Rollo and Nathan got in, and Jonas began to wheel them along towards the house.

The boys sat in the wheelbarrow, with their faces towards Jonas; and pretty soon they wanted him to tell them a story.

"Well," said Jonas, "I will. Once there was a boy, and he had a room where he used to study. He had a fire in his room, because it was winter. His father charged him that, whenever he went out of his room, he should take the fire down off the andirons; for he said that, when a stick of wood was left burning upon the andirons, there was great danger that it would burn in two, and the ends fall down, and some coals roll out, and set the room on fire."

"Yes," said Rollo; "my father told me a story of a room that got on fire in a tavern, once, in that way."

"What was the story, Rollo?" said Nathan. "Tell it to me."

"No," replied Rollo; "I want to hear the rest of Jonas's story now."

"Well," said Jonas, proceeding with his story, "the boy usually neglected to take his fire off the andirons, notwithstanding his father's injunctions; and his father was afraid that, some time or other, his fire would fall down, and the house get burned up."

"I would not have let him have any fire," said Rollo, "if I had been his father."

"One day," continued Jonas, without taking notice of Rollo's remark, "his father went into his room, and he found a stick lying across the andirons, nearly burned off. So he took the tongs, and broke it in two, gently, and laid the ends over in the corners, as if the stick had burned off, and fallen over. Then he took two or three coals, and laid them out on the hearth near the floor, and one large coal he put out upon the floor, about six inches from the edge of the hearth; and then he went away."

"Why, Jonas," said Rollo; "that would set the house on fire."

"After he had waited some minutes,' continued Jonas, "until he thought it was time for the fire to begin to blaze up, he called to the boy, who was out in the yard, and asked him to go into his room, and bring him out his dictionary. So the boy went in, and presently came running out, and said his room was on fire. So his father ran in, and poured some water on the place, out of a pitcher, and put it out. The boy was very much frightened. He thought that the stick had fallen down of itself, and that he had almost burned his father's house up."

. Here Jonas put down the wheelbarrow; for he had got to the great gate, and of course he had to stop to open it. When he had opened the gate, he wheeled the boys through, and then stopped to shut it.

"That was a good plan," said Nathan.

"No," said Jonas, "I don't think it was a good plan."

"Why not?" said Nathan.

"Why, it wasn't honest," replied Jonas. "Children ought always to be honest with their parents; and parents ought to be honest with their children."

QUESTIONS.

Had Jonas spoken to Rollo about the pole before this? On what occasion? What two names has the bright star which is near the pole? What did Jonas call the stars by which he found the Pole Star? How many of them are there? In what form are they arranged? What is the astronomical name of the constellation? Does the Great Bear include more or less than the seven Pointers? Is it a large or a small constellation? What other constellation did Mr. Holiday show them? Relate the story which Jonas told the boys in coming home. What was Jonas's reflection on this story?

CHAPTER XI.

ORION.

Mr. Holiday's business often led him away from home for a distance of twenty or thirty miles, and on such occasions he often took Rollo and Jonas with him. Jonas went to drive, and to take care of the horse, and Mr. Holiday used to allow Rollo to go, because he always enjoyed such excursions very much; and, besides, he generally derived instruction, as well as amusement, from them.

One morning, in the early part of the winter, Mr. Holiday said, at the breakfast-table, that he was going away that day to come back the next; and Rollo immediately proposed to go with him.

"Very well," said his father. "I have no objection. You may tell Jonas to have the horse and sleigh ready at ten o'clock; and tell him to put in the front seat."

The sleigh in which Mr. Holiday used to make his journeys, when the ground was

covered with snow, had two seats. The back seat was fixed, but the front one was movable, so that it could be taken out and put in at pleasure. When only two persons were going to ride, Jonas usually took out the front seat, and put it away in the chaise-house. But when more than two were to ride, then he would put it in.

When Jonas drove Mr. Holiday on his excursions, he always rode upon the front seat, for it was not only nearer the horse but it was also higher; so that for a double reason it was the most convenient seat for a driver to occupy. Rollo, however, when he rode with his father and Jonas, sometimes rode on the front seat with Jonas, and sometimes on the back seat with his father. When it was pleasant, and the cold wind did not blow much in his face, he sat upon the front seat, where he could see better. But if he became cold, he usually sat in behind with his father, where it was much more easy to keep warm.

The day on which Rollo took the ride which is to be described in this chapter, it was very pleasant. The sun shone and the air was still, and as the direction of their

journey was towards the south and west, the rays of the sun shone upon them fully, for many hours. They reached the place of their destination about the time the sun went down. It was a pleasant little village. Jonas went to take care of the horses at the stable, while Rollo and his father went into the house. Mr. Holiday ordered supper, and then went out into the village to find the man with whom he was going to do his business. In the mean time, Rollo waited in the little parlor where the tea-table was to be set. There were some books on a table in the room, and he sat down before the fire, and began to read the books.

In about half an hour, his father came in, and Rollo asked him if he had finished his business.

"Why, partly," replied his father. "I do not know but that I shall have to go on ten miles farther, this evening. If I do, should you prefer to go too, or to wait here by this comfortable fire?"

"I should rather go, a great deal," said Rollo.

"It will be pretty cold," said his father.

"Never mind," replied Rollo. "I sha'n't mind the cold."

"We had the sun's rays upon us this afternoon," said his father, "which kept us warm. But you will find it very different this evening. Besides, we have got to go across a large pond, where it will be bleak, if there is any wind."

The argument of the pond, instead of operating to induce Rollo to remain where he was, only increased his desire to go; for he thought that it would be very pleasant to ride over a pond, in a winter's night, by starlight.

Mr. Holiday was willing that Rollo should decide the question for himself. In fact, he thought that he would not be very cold if he should go with them, for they had four buffalo skins in the sleigh, which were very warm; and he knew, therefore, that Rollo could be well protected from the cold.

Accordingly the plan was so arranged, and after tea Jonas brought the horse and sleigh up to the door. When Rollo first came out, he thought it was not very cold. He had become well warmed in the little parlor,

and he was much wrapped up with clothing.

He had on thick boots and a warm great-coat, lined and wadded. He wore a fur cap upon his head, which covered his ears, and a fur tippet about his neck.

It was, however, really very cold, although Rollo did not begin to feel it much at first. But, though cold, it was a pleasant evening. There was very little wind, and there were no clouds.

"O father," said Rollo, looking up; "look at the sky; see how full of stars it is."

The sky was indeed very full of stars. The galaxy, or the milky way, as it is sometimes called, was very bright. Rollo looked at the stars a moment, and then he got into the sleigh. His father advised him to take a seat with him, behind; but Rollo said that he wanted to sit with Jonas, and see the pond, when they came to it.

"I am afraid you will be cold," said his father.

"No, sir," said Rollo; "I don't think it is cold."

So Rollo took his place, by the side of Jonas, on the front seat, and they rode along

After going at a brisk pace for a few miles, they came to the top of a hill, where the pond first appeared in sight. It looked like a great level field covered with snow. They could see a dark line winding along in a gently-serpentine direction across the surface of it. Jonas said that this was the road which they were to take in crossing the pond.

The horse went rapidly down the hill, and before long they were upon the pond. There was not much wind, but a light breeze blew keenly towards Rollo's face, and made his nose and his cheeks cold. So he said he meant to turn round, and face towards his father.

His father proposed to him to come and sit upon the back seat; but he said he should be warm upon the front seat, if he only turned round. So he put his feet over the seat, and enveloped them in the buffalo skins which were down in front of the back seat, and the buffalo which had been before him he drew up over his shoulders, so that now he had a very good place indeed. He could see, all around him, the shores of the pond, with the lights in the farm-houses on the

land, and all the constellations which were spread out before him in that quarter of the heavens towards which he was looking.

"O father," said Rollo, "I see three stars all in a row. I wish I knew the names of them. Could you look round and see, father?"

"Why, not very well," said his father. "I cannot look round, I am so muffled up."

Rollo, being seated on the front seat, with his back to the horse, of course was looking at that part of the sky which was behind the sleigh, so that his father could not see the constellations in that quarter of the heavens.

"Let me see," said his father; "we must be going nearly west, so that that part of the sky is the eastern part. Orion must be rising about this time. Perhaps the stars which you see are the stars in the belt of Orion."

"In the belt of Orion?" repeated Rollo.

"Yes," said his father. "The most beautiful constellation in the sky is Orion; and early in the winter it rises in the evening. Orion was a hunter, and he has a

belt · and in his belt are three beautiful stars, all in a row."

"Well, father," said Rollo, "tell me some other stars that ought to be near, if it is really the belt of Orion that I see, and then I will tell you if they are there."

"Very well," said his father. "If they are the three stars in the belt of Orion, they lie in a line one above the other, not one by the side of the other. I mean by that, that, if there was a line drawn through them, and continued each way, it would be a line running up and down in the sky, not a line extending from one side to the other."

"Yes, sir," said Rollo; "this row of stars is in a line up and down."

"And off on each side of the little row of stars are two other bright stars, one on each side."

"How far off, sir?" said Rollo.

"About twice as far, I should think, as the length of the little row of stars."

"Yes, sir," said Rollo; "I see one of them. Yes, I see them both. One is off on one side, and the other is on the other side."

"Yes; then I have no doubt it is Orion that you see. One of the stars that you

last found is in his foot, and the other is in his shoulder."

"I wish I could see his shape," said Rollo, all drawn out in the sky."

"It would be very convenient, I have no doubt," replied his father. "Pretty near the lowest of the three stars in the row, there is a faint cluster of stars, towards the south."

"Yes, sir," said Rollo; "I see them."

"They are in Orion's sword," said his father.

"I see them," said Rollo.

"Now, look at all the stars in the constellation again, and notice how they lie in respect to each other, so that you will know the constellation when you see it again."

"Yes, sir," said Rollo; "I mean to look for it every evening; only I shall forget where to look."

"You must look in the east, at this time of the year, and at this time of the evening. In the spring of the year, Orion is in the west in the evening. Orion rises in the east, and passes over just like the sun, every day, and sets in the west. Only in the autumn, and early in the winter, he rises in the evening, and sets in the morning; and

in spring, and early in the summer, he rises towards the morning, and sets in the evening. If it were April now, we should see Orion in the west, at this time of the evening, just going down.

During this conversation, Jonas looked round several times to see Orion. He told Mr. Holiday that there was a very bright star down near the horizon, and pretty nearly in a line with the little row of stars in Orion's belt.

"Yes," said Mr. Holiday; "that is Sirius, — the brightest star in the sky. Do you see it, Rollo?"

"Yes, sir," said Rollo, pointing; "there it is."

"There is one more star for you to find," said Mr. Holiday, "and that will do for your lesson to-night."

"What is the name of it, sir?" asked Rollo.

"Aldebaran," replied his father. "Aldebaran is opposite to Sirius, almost in a line with the little row, only above, and about as far above as Sirius is below."

Rollo and Jonas looked for Aldebaran but they were not sure that they found it

So Mr. Holiday turned partly round, and showed them Aldebaran. Aldebaran was quite high in the sky, and Sirius was quite low, and the little row of stars in Orion's belt was between the two, and pointed on the one side to the one, and on the other side to the other. Thus it was that Rollo came to know Aldebaran, and Sirius, and the bright constellation of Orion.

QUESTIONS.

What were the circumstances of the ride described in this chapter? At what season of the year was it? Did they intend to ride in the evening, when they left home? How came they to ride in the evening? How were the party seated when they set out in the evening? What change did Rollo make in his position when they came upon the pond? What is the name of the constellation which attracted Rollo's attention? Towards what quarter of the heavens was he looking? How many stars did he notice particularly at first? In what part of the figure of Orion are these three stars situated? What are the names of the other two stars which Rollo learned? How is Sirius situated in respect to the three stars in Orion's belt? How is Aldebaran situated? Where are these stars in the evening in spring?

CHAPTER XII.

SIRIUS.

Rollo was very much interested in the information which his father gave him about the constellation of Orion, and the stars in its vicinity. Jonas was much interested too. He took great pains to fix the names and the relative position of the stars in his mind. He was more careful to do this than Rollo was; for he was aware that, if he should forget any thing which Mr. Holiday had said, it might be very long before he should have a suitable opportunity to ask him to repeat it. Accordingly, for several evenings after this, he went out and looked at these stars, repeating to himself their names, and noticing particularly their respective situation, so as to impress the knowledge which he had acquired as firmly as possible upon his memory. Rollo, however, thought little more about it all winter.

Towards the close of the winte , how-

ever, a circumstance occurred which brought the subject up to his mind again. It was in February, near the close of the month. There had been a rain storm which had melted the snow very much. The streams had been swollen so as to overflow their banks, and large pools of water were formed in all the low places in the fields. Down upon the meadows, too, in front of his father's house, there were large ponds of water formed by the overflow of the brook which ran through it.

After the rain, the wind blew cold from the north-west for two days, and this was succeeded by a hard frost, which continued for several days and nights, until all these pools and ponds were frozen over. Rollo wanted to go down upon the meadows, and skate. His father said that he might go. So he took his hand-sled, and put Nathan upon it, giving Nathan his skates to hold; and thus he proceeded down towards the ice, drawing Nathan over the icy surface of the ground.

The sled was what boys call a *framed* sled; so that it was quite light, though it was pretty large. It had a wooden tongue,

instead of a rope, to draw it by. A tongue is better than a rope, because you can *push* the sled by a tongue, as well as pull it; and, besides, by means of a tongue the sled can be turned round more easily.

Rollo asked his father if he might make a fire upon the ice that afternoon. He thought of this after he had started with Nathan; so he went to the parlor window, and knocked, and asked the question.

"No," said his father; "you must not make a fire. But if you will collect a heap of sticks and logs, for fuel, we will all go down this evening, and set it on fire."

Rollo liked this plan very much. So he went back to Nathan, and told him. Nathan asked Rollo if he thought that his father would let him go down and see the fire.

"Yes," said Rollo, "if you'll help me make the pile of wood."

"Well," said Nathan, "I will."

So Rollo and Nathan went down to the meadows together.

When they reached the ice Rollo put on his skates, and Nathan took his seat upon the sled, ready for Rollo to give him a ride. There were four stakes set into the sides of

the sled, two on each side. Nathan sat with his back towards the forward part of the sled, because Rollo was going to push him, and not draw him; and of course he must sit with his back to Rollo in order to face the way that he was going.

When Rollo was ready, he took up the tongue, and began to skate slowly along pushing the sled before him.

The sled glided smoothly over the ice; and Nathan had a fine ride, until at length they came to the place where Rollo said it would be well for them to make their fire. The pond at this place was at the margin of the meadow, where it was bounded by high land covered with forest-trees. The snow had been nearly melted away from this hill side, and Rollo saw that there were a great many sticks and half-decayed branches lying about upon the ground.

"Now, Nathan," said Rollo, "here is plenty of wood for our fire, only I can't go and get it, because I have got my skates on. You must go up under the trees, and throw the sticks down to the edge of the ice, and I will put them upon my sled, and so draw

them off to the place where we are going to have the fire."

Nathan approved of this arrangement, and the boys worked industriously more than two hours, until at last they had made quite a large heap of fuel. They piled it up upon the ice near the middle of the pond. Nathan said he thought that it would make a magnificent fire.

After they had collected all this fuel, Rollo gave Nathan some more rides upon his sled, and then they went home. It was not quite tea-time, and so the boys went out to find Jonas, to tell him about the fire, and to ask him if he would go down with them in the evening, and see it burn.

"Yes," said Jonas, "and we will look for the stars in Orion. I have not looked for them these two or three months."

"No," said Rollo; "it won't do any good. I don't believe we can find them. They must be all scattered about before this time."

"Why, no," said Jonas; "they don't get scattered about. The stars always keep together, just in the same places."

"No," said Rollo; "father said they moved about the sky."

"Yes," replied Jonas, "they move over the sky · but they all move together, and keep as far apart from each other at one time as at another, all the way. They don't move about *among each other* at all."

"Don't they?" said Rollo.

"No," replied Jonas; "certainly not. Those three stars in Orion's belt have been in just such a row always; and they never move out of it; and Sirius has been just so far from them, off at one side."

"Then perhaps we can find them to-night," said Rollo.

"Yes," replied Jonas; "I have no doubt we can. Only they will not be in the east. Your father said that they were in the west in the evenings in spring, and it is pretty nearly spring now."

"We'll look in the west, then," said Rollo.

"Or overhead," replied Jonas; "perhaps they have not got farther than overhead yet."

Jonas was right in his expectation of finding the constellation of Orion, and the bright stars near it. For, when they went down that evening, they saw the stars forming that

constellation, and also Sirius and Aldebaran, in precisely the same relative situation in respect to each other which they had occupied earlier in the winter, — though the whole group was now in a different part of the sky.

There was, however, one bright star between Sirius and Orion which Rollo did not recollect seeing there before.

"No," said his father, "it was not there before. It has come among these constellations. It is one of the wandering stars."

"Wandering stars," repeated Rollo.

"Yes," said his father. "Almost all the stars keep exactly the same places in respect to each other. They all rise and set, it is true; but then they go together, and each keeps its own fixed place among the rest. But there are a few that go wandering about among the rest, sometimes here, and sometimes there."

"How many are there, sir?" asked Rollo.

"There are only four that are very bright."

"What are their names?" asked Rollo.

"Venus, Mars, Jupiter, and Saturn," replied his father.

"Which is this one coming into Orion?"

"I don't know," said his father. "Perhaps it is Jupiter."

"I wish I knew," said Rollo.

Nathan was impatient to go and set their heap on fire, and so the whole party walked along. Rollo's father and mother were both with them; and, when they got to the ice, Rollo put on his skates, and skated along to the place, pushing Nathan before him on the sled, as he had done in the afternoon. His father and mother walked along upon the hard snow at the margin of the ice, until they came opposite to the heap of fuel, and then they walked carefully over the ice to it.

The heap burned well, and it made a beautiful fire, which illuminated the whole field of ice, and gleamed on the forests and hills around.

After a short time, Rollo's father and mother concluded to go home, and they told Rollo and Nathan that they might remain there with Jonas for about half an hour.

"How can I tell when it is half an hour?" said Rollo.

"O," said his father, "you can guess pretty near; — no — you can tell by Sirius. See, as we stand here, you observe that it appears

a little way above the top of that tree over on the bank."

"Yes, sir," said Rollo.

"Well, now you may wait until Sirius gets down into the tree."

"Well, sir," said Nathan.

"Only," continued his father, "you must be careful to stand in exactly the same place as now, when you make your observation."

"Yes, sir, I will," said Rollo.

So his father and mother walked slowly away. After they had gone a short distance, Rollo called out, in a loud voice, —

"Father!"

"What," said his father, looking round.

"Will you just tell me the name of that little cluster of stars out there a little way beyond Aldebaran?"

"Yes," said his father; "the Pleiades."

QUESTIONS.

Describe the manner in which the sheets of ice were formed, as stated in this chapter. Describe the sled which Rollo took with him to the ice. How was Nathan placed upon it, when taking his ride? In what manner did they arrange their work in getting the wood? What conversa

YOU WAIT UNTIL SIRIUS GETS INTO THE TREE.—Page 160.

tion did Rollo hold with Jonas about the stars? Did Rollo expect to be able to find and recognize Orion? Why not? What did Jonas say? Did they find Orion? In what quarter of the heavens was it? What other stars did they find? What did Rollo's father say about wandering stars? What are the names of the four brightest? What is the name of the cluster which Rollo asked his father about when he was going away? Where is it situated?

CHAPTER XIII.

PARALLAX.

Once upon a time, Rollo and his father were travelling in a steamboat by night, when an opportunity occurred to teach Rollo something about the distance of the stars, and the mode by which the astronomers determine the distance.

The route which Rollo and his father were taking, was one which was performed partly by steamboat, and partly by railroad; and it was so arranged that they were to reach the port where the passengers were to be transferred from the boat to the cars, at a little after midnight. They were then to continue their journey on the railroad, and reach their place of destination in the morning.

About half an hour before it was time for the boat to arrive at the port, a waiter walked through the cabin of the steamboat, between the rows of berths and cots, which were filled with passengers asleep, ringing, as he walked,

a huge bell, which was intended to wake the passengers up. Rollo was sleeping in a berth directly over his father's. He lifted up his head, looked around eagerly, and, as soon as he recollected where he was, he looked down into his father's birth, and said, —

"Father, what is that bell for? Is it for fire?"

"No," said his father; "only to wake us up."

"O!" said Rollo, in a tone of voice which expressed that he felt relieved. Rollo would not seriously have supposed that the bell was for fire, if he had been fully awake; but, being suddenly aroused by such a loud sound, in such a strange place, it is not surprising that he was a little alarmed.

When Rollo found that the bell was for them to get up, he was in great haste to obey it. His father was much more deliberate in his motions, and at length Rollo told his father, that he thought they had better be quick, or the steamboat would get to the land, and the cars would go off and leave them.

"No," said his father; "they generally give us time enough."

Just then, Rollo heard a little bell ring

that sounded as if it was up on deck. It was a bell in the engine-room, but it was rung by a man in the wheel-house. The wheel-house is a small room or closet, with windows in front, built on the deck, in the forward part of the boat, where the helmsman stands to steer. The windows in the front of the wheel-house are for him to look out, and see where he is going. In pleasant weather, he has these windows open; but when it rains or snows, or when the wind blows heavily, he keeps these windows shut, and so looks through the glass.

There is a large wheel in this place, which is the reason why they call it the wheel-house. The wheel has handles to it, all around, for the man to take hold of, to turn the wheel one way or the other. There is an axle to the wheel, and a rope passes once or twice round the axle. The two ends of the rope are carried along the whole length of the vessel to the stern, where the rudder is. The ropes pass on the under side of the promenade deck on little pulleys. The ends of the rope are fastened to the rudder, one on one side, and one on the other. Thus the man who stands in the wheel-house can look out forward

through the windows, and see which way the steamboat ought to go; and then he can turn the wheel one way or the other, and so steer the boat just as he pleases.

There is also in the wheel-house a little bell-pull, with a wire leading from it to the engine-room. The end of the wire in the engine-room is connected with a bell, so that the helmsman, while he is steering the steamboat in the wheel-house, can make the little bell ring in the engine-room, whenever he wants the engineer to stop the engine.

Now, it happened that, while Rollo and his father were preparing to come up from their cabin, the helmsman saw a sloop before them, which was sailing almost exactly across their course. So he pulled the bell, to make the engineer stop the engine, until the sloop should have time to get by.

Rollo understood this; at least he understood that there must be some difficulty in the way of going forward, for he had very often stood by the wheel-house to see the helmsman steer; and he had watched him, when there was any difficulty in the way, and had seen how he made the signal to the engineer. He wanted his father to make

haste, and go up, and see what the difficulty was.

"You may go up whenever you are ready," said his father, "and I will come up by and by."

So Rollo went up the cabin stairs, and came out upon the main deck. Here, however, he could not see very well; so he went around to the little staircase which led up to the promenade deck. Before he got up, the bell was rung again, and the engine put in motion, so that by the time that he reached a place where he could see, the boat was going on as rapidly as ever, and the sloop was but just visible, as she was rapidly receding into the distance, off on one side of the boat.

There were two or three stools under an awning, near the place where Rollo was standing, and he sat down upon one of them. In a short time, his father came up, and took his seat at his side.

"How long will it be now, father, before we shall get in?" asked Rollo.

"I should think it would be twenty minutes," replied his father.

"And what shall we do all that time?" said Rollo.

"O, we can sit here and look at the stars I can see several different kinds of stars; at least, what we might call stars."

"How many?" asked Rollo.

"Why, in the first place," said his father, "there is Sirius."

So saying, his father pointed to a bright star which was before them, about thirty degrees above the horizon.

"Is that Sirius?" said Rollo.

"Yes," replied his father.

Then he pointed to another star, which looked very much like Sirius, only it was not quite so bright, and he said that that must be a planet.

"How do you know that it is a planet?" asked Rollo.

"Because," replied his father, "I know there isn't any *star* which belongs there."

"Is not a planet a star?" asked Rollo.

"Why, we may call it a star, just as we may call those little sparkles in the water stars," replied his father.

"What little sparkles?" said Rollo.

"Come with me," replied his father, "and I will show you."

So Rollo went with his father to the side

of the boat, and they looked over together. The water came foaming along the side from under the paddle-wheels, and in the midst of it, Rollo perceived, every now and then, a bright spark which sailed along a moment, and then became suddenly extinguished.

"There," said his father, "we might call those sparkles stars. For instance, a man might say that he looked over the bows of the boat, and saw the water full of little stars."

"But, father," said Rollo, "the water is not full; there is only now and then one."

"I presume we should see more of them at the bows," said his father.

"Well," replied Rollo, "let us go and look."

So Rollo and his father walked along together to the forward part of the boat, on the promenade deck. The promenade deck is the upper deck. Rollo stopped a moment, when they reached the wheel-house, to look in at the man who was steering. It was almost dark in the wheel-house. There were two small boxes which had compasses in them, for the man to steer by, when there was no land in sight. There was a light in

each of these boxes, which was placed in such a manner, as to shine upon the compass, so that the helmsman could see which way the needle pointed; but it did not shine much into the wheel-house itself.

"I should want a great deal more light than that," said Rollo, "if I was going to steer."

"I suppose that the helmsman would like to have more light, if he could," said his father.

"Well, he might have more," rejoined Rollo. "He might have a good bright lamp hung up in his wheel-house."

"That would not do any good," said his father, "for that would only illuminate the things that are in the wheel-house; and what he wants to see, are the things out over the water, — such as the vessels coming and going, and the land. If he could have a light which would shine upon *them*, it would do very well; but to have a bright light hung up in the wheel-house, would only tend to dazzle his eyes."

"Yes," said Rollo: "I did not think of that."

"They always keep the wheel-house dark, for the eye is more sensitive in the dark,' said his father. "They have a small light to shine upon the compass-card, and that is all."

The promenade deck did not extend any farther forward than the wheel-house; so that, while Rollo and his father had been holding the preceding conversation, they stood at the end of it, near a railing which passed across in a line with the forward part of the wheel-house. At length Rollo said,

"Come, father, let us go and see the sparks."

There was a steep ladder which led down from the forward part of the promenade deck to the forecastle. Rollo and his father descended this ladder. As soon as they reached the deck below, they walked forward to the bows, where they climbed up upon the bulwarks, and looked down to the water.

The boat was moving swiftly along, so as to plough up the water with great force, and Rollo saw, to his great delight, that the dashing waves were, to use his father's expression, full of stars. They looked like

sparks of fire, which came flying out on each side of the cut-water, and glided swiftly along the bows.

"What makes them?" said Rollo.

"I don't know," replied his father.

"Why, father!" said Rollo; "don't you know?"

"No," replied his father. "I have heard it said that they are produced by some kind of animalculæ in the water."

"What are animalculæ?" asked Rollo.

"The word *animalculæ* means small animals," replied his father. "Some people say that these little stars are some kind of animalculæ; but if they are, I don't understand why they don't shine, except when the water is agitated. You see that where the water is dashed away each side of the bows, and where it comes out from under the paddle-wheels, we see these stars; but they do not shine where the water is still."

After looking at these stars in the water for some time, Rollo and his father went back to their seats under the awning. Here Rollo's attention was soon attracted by the sight of a star, as he supposed, which was

that we have not altered our course. But the light has moved along the horizon several degrees; so that it appears, now, in a very different direction from what it did before. And yet it has not moved itself; it only changes its direction because we move."

"How do you know," asked Rollo, "that it does not move itself?"

"Why, I don't know what movable ligh there could be there."

"There might be a man," replied Rollo "carrying a lantern along the shore."

"But the light of a lantern could not be seen so far," rejoined his father.

"Perhaps it is not very far," said Rollo. "We may be pretty nigh the shore."

"But we have sailed two or three miles, at least," replied his father, "since I first saw the light. Now, if we were so near the shore as to be able to see the light of a lantern, we should have got by it entirely before this time, and have left it far behind us. But, though we have sailed two or three miles, the light has only advanced along the horizon a little way; and so I judge that it must be five or six miles off. And if it is five or six miles off, it must be some large

ight ; and I cannot think of any thing which t is likely to be, except a lighthouse."

"I rather think it is a lighthouse myself,' said Rollo.

"If we watch it," said his father, "we shall see that it moves slowly along, as we advance on our way. Pretty soon, it will be exactly opposite to us. Then presently it will begin to pass along behind us, and finally will get far astern. That changing of its direction in consequence of our moving along, while it is really at rest itself, is its *parallax*. Now, the way to determine how far off any object is, when you cannot measure directly, is by observing its parallax ; because the nearer to us the object is, the greater will be its parallax."

"I don't understand that exactly," said Rollo.

"Why, the nearer it is," replied his father, "the more rapidly it will appear to move along when we are passing it. For instance, if there was a man out on the water here, with a lamp in his hand, only a quarter of a mile from where we are, as soon as the lamp came into view, we should see it appearing to glide along very swiftly; and in a very

few minutes, it would have passed out of sight astern."

"I wish there was one," said Rollo.

"So do I," replied his father; "but that cannot be. We cannot really witness that experiment, but you can see that it must be so, from the very nature of the case. So you see that, if any object is at rest, at a distance from us, we can judge how far off it is, by observing how fast it seems to move, while we are going by it."

Rollo's father was mistaken in saying that they could not have the opportunity to witness such a phenomenon as he had described, for, just at the moment when he had finished his explanation, a light suddenly came into view, a short distance before them, on the same side of the boat where they were sitting, and it came gliding swiftly along, so that it was almost opposite to them before Rollo could recover from his surprise.

"Why, father, what is that?" said he.

"I don't know," said his father. "It is some light very near, for it has a great parallax; but I don't know what it can be. You may go forward, Rollo, and see if you can find somebody to ask what it is."

Rollo came back in a few minutes, and said that there was a man standing near the wheel-house, who told him that it was a light upon a vessel at anchor. The man told him, he said. that all the vessels had to carry lights, so that the steamboats might know where they were, and not run against them.

By this time, the lighthouse had got considerably astern, but it was yet distinctly in view, while the light upon the vessel had almost disappeared, as the steamboat had got completely beyond it.

"Now, you understand something about parallax," said Rollo's father. "The lantern hung up on the vessel is nearest to us. Next comes the light upon the lighthouse; next the planet; and Sirius is farthest off of all; and they all appear to change their direction from us, more or less rapidly, according to their distance. The vessel's lantern, a few minutes ago, was directly before us, and now it is almost directly behind. It has changed its direction nearly a hundred and eighty degrees in a few minutes. The lighthouse has been moving slowly along, and has not changed its direction more than forty or fifty degrees, perhaps, all the time

that we have been looking at it. The planet is farther off still, and we cannot see that it has changed its direction at all; though it has changed its place a very little; and finally Sirius, which is most remote of all, even if we were to observe it with the very nicest instruments, would not seem to have moved in the least degree."

"Yes, father, I understand," said Rollo.

"We can observe the parallax, very easily," said Rollo's father, "in the case of these lights, and other things so near; but we cannot perceive the parallax of the heavenly bodies, without instruments and nice observations. The astronomers have such instruments, and they note how much the heavenly bodies change their direction from us, when they are observed from different places, and from that they can calculate the exact distance."

"I don't see how they can calculate the exact distance," said Rollo.

"No," said his father, "I do not suppose you can. You can only understand a very little about such a subject. I only wanted to give you some general idea of the way they measure the distances of the heavenly bodies

It will be of some use to you sometimes, in enabling you to form some judgment of the distance of objects you see when you are riding or sailing. Sailors can judge of the distance of a mountain, when they are sailing along the coast, by observing how fast it seems to move along the horizon."

Just at this moment, Rollo, who happened to be looking at the lighthouse, observed that it was beginning to move very swiftly around towards the stern of the boat.

"Why, father," said he, "the lighthouse is moving away very fast now."

"Yes," said his father; "I see it is changing very fast; but that cannot be parallax. It must be because the boat is turning out of its course. I presume we are turning to go into the harbor."

So Rollo and his father rose from their seats, and walked forward, in order to be able to see more distinctly what was going on. They advanced along the promenade deck towards the wheel-house, and took their stand by the side of the wheel-house, near the ladder which led down to the main deck below.

There was a railing before them to keep them from falling off.

They could see, before them, the dim form of the land, with the outlines of the buildings of a town relieved against the sky, and on the water between them and the town, they saw quite a number of lights which belonged to vessels lying in the harbor. One vessel was so near that they could see the dark form of her hull floating on the water. The other lights were at different distances. Rollo was very much interested in observing the different degrees of rapidity with which they appeared to move, as the steamboat glided by them. He found that he could tell very easily which were near, and which were remote, by observing their apparent motion.

"Father," said Rollo, after watching these lights a little while, "I can tell which lights are nearer than the others, by their moving quicker; but I cannot tell how far off any of them are."

"No," replied his father; "I know you cannot. It requires some nice measurements and observations to do that."

"But I thought you said, father," rejoined

Rollo, "that they could tell how far off the stars are, without measuring, — by the parallax."

"Yes," said his father; "that is, without measuring the distance to the stars; but they have to measure some other distances. For example, if we were going to ascertain how far off we were from that lighthouse half an hour ago, it would be necessary to have taken an observation of its direction from us exactly, with an instrument. Then, after a time, when we should have sailed a certain distance, we should have to observe the direction again, very carefully; and we must also note down very exactly the distance we had sailed. Then we could make the calculation."

"How should we do it?" asked Rollo.

"O, you cannot understand that yet," said his father. "In order to know how to make such a calculation, it is necessary to understand trigonometry."

"Is trigonometry hard?" asked Rollo.

"No," replied his father, "not if the pupil is old enough to study it."

Just at this moment, Rollo heard a little snap in the wheel-house, and immediately afterwards the bell rung in the engine-room.

and the engine stopped. He looked up, and saw that the steamboat was just coming up to the wharf. There were a great many persons coming and going upon the decks of the boat, and he could see a few persons also upon the wharf. There was a lantern on the wharf, upon a post, but it did not give much light.

There was a man standing upon the forecastle, below Rollo and his father, who had a coil of rope in his hands, which he was preparing to throw on shore. He made, first, a large coil with his rope, which he then divided into two parts, holding one part in each hand. A moment afterwards, he threw the two coils, first the one in his right hand, and then, immediately following it, the one in his left. The end of the rope went away over upon the wharf; and the man who was standing there immediately seized it, and began drawing it in.

"Come, father," said Rollo; "it is time for us to go."

"Yes," replied his father; "I think it is."

So our two travellers walked back to the part of the boat where there was a staircase leading down to the main deck. They went

down the staircase, and came upon that part of the deck which was in front of the entrance to the ladies' cabin. Here there were a great many passengers collected, waiting for the moment when they were to go on shore. The little bell in the engine-room was rung repeatedly, and the engine was sometimes stopped, and sometimes set in motion, until finally the boat was brought up to the wharf, and secured there.

"Please to stand off the plank, gentlemen,' said one of the hands, who stood near the place where they were to go off from the deck of the steamboat to the wharf.

Rollo looked down, and saw upon the deck of the boat a very wide plank. In fact, it was formed of two planks fastened together, side by side, so as to be wide enough for two or three persons to walk over together. It was made to be placed across from the steamboat to the wharf, for the passengers to walk over, when they wished to go ashore, or to come on board the boat.

The gentlemen who had been standing upon this plank stepped off from it when the order was given, and then four men took hold of it, one at each corner, and lifted it

up. It was so heavy that it required four men to lift it easily. The men then threw the plank forward in such a manner that it fell with one end resting upon the wharf, and the other end on the deck of the boat. Thus it formed a sort of bridge from the boat to the land. The passengers immediately began to pour over the bridge in a strong current, men, women, and children, all crowding forward together; and thus they all soon passed safely to land.

They found the train of cars all ready for them, and the locomotive hissing upon the track. The company crowded into the cars, all anxious to get a good seat.

"Well, Rollo," said his father, when they were at last fairly seated in the car, "here we are safe in the car; and I suppose you are glad."

"Why, yes, sir," said Rollo; "but I am not very glad, for I like to look at the lights in the vessels."

"Perhaps you can make observations of the same kind on the shore," said his father. "We may see some lights in the houses as we pass along."

"I'll look," said Rollo, "and then I can tell how far off the houses are."

"Yes," said his father; "only now we are going much faster than we were in the boat, and that will make the parallax of any light greater than it would be as seen from the boat. So you must make some allowance for that."

"How much, sir?" asked Rollo.

"O, it is impossible to say how much," replied his father, "since I don't know how much faster we go."

However, Rollo was prevented from making any observations on parallax, while going along in the cars, for at first there were no lights to be seen. It was so early in the morning that nobody had got up; and by the time the morning was so far advanced that lights began to appear at the farm-house windows, Rollo was fast asleep in the car, with his head reclined against his father's shoulder.

QUESTIONS.

Where were Rollo and his father when the conversation occurred which is described in this chapter? What is the name of the star which they saw in the sky? What other

heavenly body did they see near it, which resembled it in appearance? What remarkable appearance did they observe in the water? Where did they go, in order to have a better opportunity to observe this appearance? What is the name used by astronomers to denote the difference of direction in which an object appears when seen from different places? How did Rollo's father know that the light which they saw in the horizon must be several miles off? What difference was there in the appearances presented by the light on board the vessel? Why did the light on board the vessel appear to move more rapidly? How did Rollo judge of the comparative distances of the vessels anchored in the harbor? What is the meaning of the word *animal cula?*

CHAPTER XIV.

THE AURORA BOREALIS.

One day, Rollo went out with his father and Nathan to gather raspberries. They went into the woods. It was at a considerable distance from the house where they lived, that they expected to find the raspberries; and, when they reached the place, the berries were not very thick, and so they kept going on farther and farther, until at last they got more than a mile and a half from home.

Instead of coming home through the woods, after they had done gathering their raspberries, they concluded to go across a field, and so come out into a road which would lead them home. Rollo's father said that it would not be much nearer, but that it would be easier walking along a road.

After they had walked about half a mile, they began to be pretty tired, and they had still a mile farther to go. So Rollo asked

his father to tell them a story, to beguile the tediousness of the way. He said he could not tell them a story very well, but he would give them some information about the sky if he could think of any thing which he had not explained to them before.

"Well, sir," said Rollo, "that will do almost as well."

"There are several distinct luminous appearances, produced in the sky by means of the atmosphere," said his father.

"What do you mean by *luminous appearances?*" asked Nathan.

"Appearances of light," replied his father.

"There is the twilight, the dawn, the Aurora Borealis, and the halo. I will explain them to you in order.

"The twilight is the reflection of the sun's light in the atmosphere after the sun himself has gone down. The rays shine up into the atmosphere, over our heads, and in the western part of the sky, and there they are reflected so as to make it light. If there are any clouds in the west, the sun's rays shine upon them, and make them appear of brilliant colors. This twilight is very useful to us; for, without it, it would become

suddenly dark as soon as the sun went down. It would be very inconvenient for people to be left suddenly in the dark, every evening, just at sunset."

"Yes, sir," said Nathan, "I think it would."

"The second luminous appearance produced in the atmosphere," continued his father, "is the dawn. The dawn appears in the east. It is caused by the rays of the sun shining upon the atmosphere in the east before the sun himself rises. If there are any clouds in the eastern part of the sky, they appear in bright colors, — but not so bright generally as the clouds in the west at sunset."

"Why are they not so bright?" asked Rollo.

"I don't know why," replied his father. "I will ask some philosopher the next time I see one. This light in the east is the dawn; it indicates the approach of day. In ancient times, it was called the *Aurora*.

"There is another Aurora, which appears in the north; but it is not followed by day. It is called the *Aurora of the north*."

"The Aurora Borealis?" said Rollo.

"Yes" replied his father. "Borealis

means *of the north*, or *northern*. It is the northern dawn, but it is not followed by day If we should get lost in the woods, and have to spend the night there, and if we could find a place where we could see the sky, we should watch it very anxiously for signs of the morning. At last, perhaps we should see a faint blush of light spreading along the horizon, and we should think it was the dawn, and that the morning was soon to come. But presently we should find the light fading away again, and soon see it disappear, showing that it was only a northern dawn, — a cold, false light, shining from icebergs and frozen seas, instead of the harbinger of morning."

"Does the Aurora Borealis come from the icebergs?" asked Rollo.

"It comes from the north, the region of icebergs," said his father; "but I do not know what it is caused by. The twilight and the dawn are caused by the rays of the sun shining upon the atmosphere; but there is no sun in the north to produce this kind of dawning."

"Does any body know what makes it?" asked Rollo.

"I believe not," said his father. "There have been a great many explanations offered, but they are none of them satisfactory."

"What *are* the explanations?" asked Rollo.

"I don't understand them well enough myself to attempt to explain them to you," replied his father. "So I will tell you about halos. A halo is a luminous appearance upon the clouds, or upon the vapors of the atmosphere, around the sun or the moon. Sometimes the halo is a bright circle. Sometimes there are bright spots at the quarters of the circle. Sometimes it is in the form of rays diverging from the sun in all directions.'

"I never saw a halo," said Nathan.

"I have," replied Rollo; "and I'll show you one some day."

Just at this time, Rollo observed that his father was looking very intently at some object at a distance before him on the road. It was a wagon coming.

Rollo observed that the horse looked very much like his father's horse.

"I wish it *was* our horse and wagon," said Rollo, "and then we could have a ride home."

"It is," said Nathan; "I am certain it is Jonas is in it, driving."

"Is it, father?" asked Rollo

"It may be," replied his father. "Jonas was going to mill this afternoon, and this is the road to mill."

It proved to be really Jonas. When he came up, Rollo's father said he might turn back, and carry them home. They accordingly put their baskets of berries into the wagon, and Jonas gave them a ride home; after which Rollo and Nathan went with him to mill.

QUESTIONS.

What is the meaning of the phrase *luminous appearance?* How many kinds of luminous appearances did Rollo's father mention? What is the cause of the twilight? Of what advantage is it to mankind? What is the cause of the dawn? By what other name is it sometimes called? What is the meaning of *Aurora Borealis?* What is a *halo?*

END OF PART IV.

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